ELECTRICAL ENGINEERING

SEPTEMBER 1949

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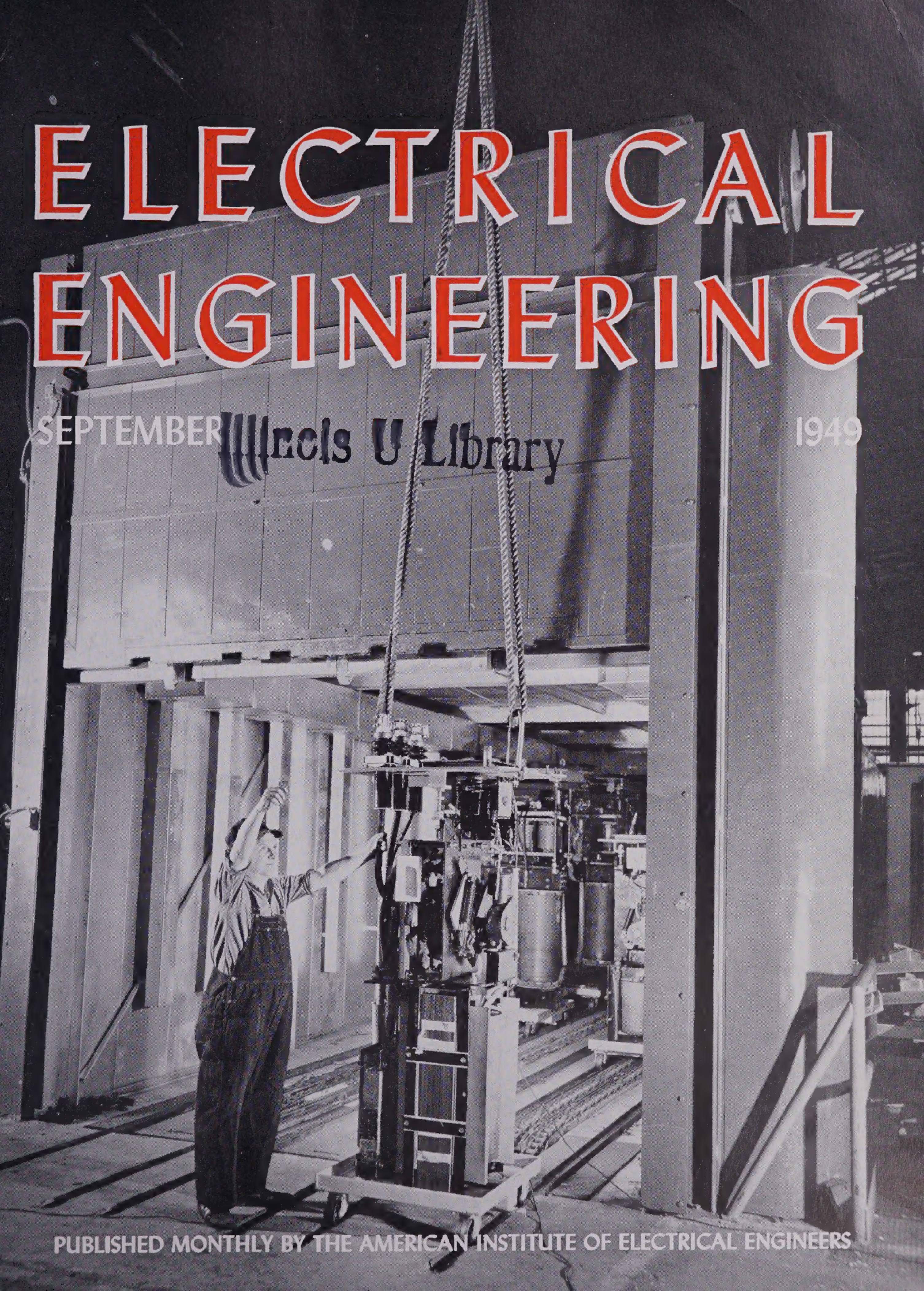

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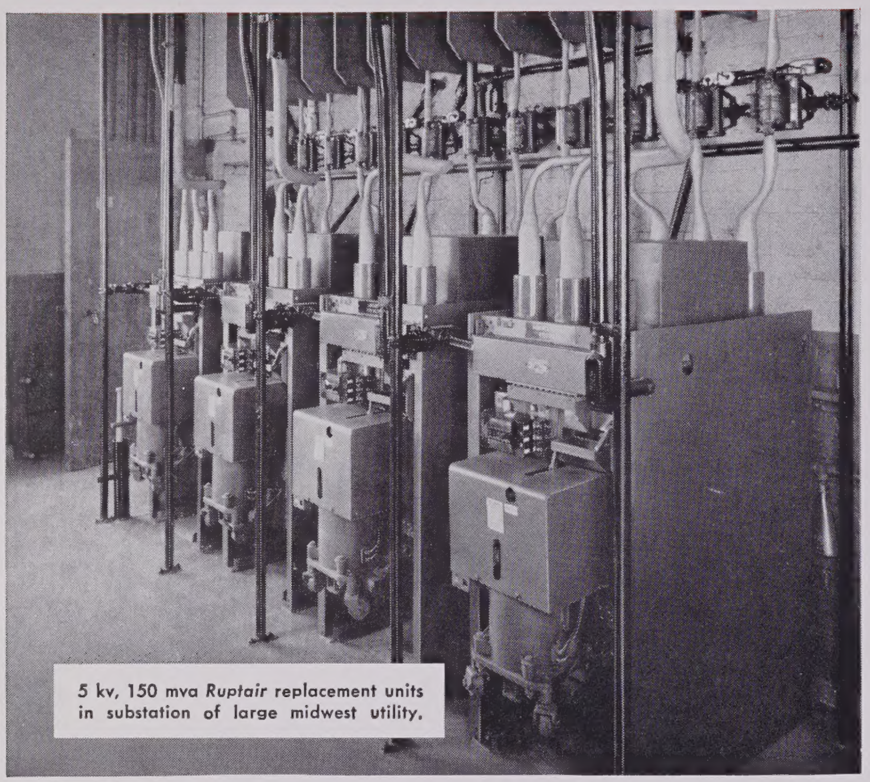

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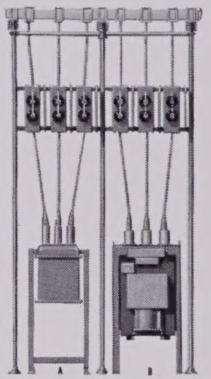

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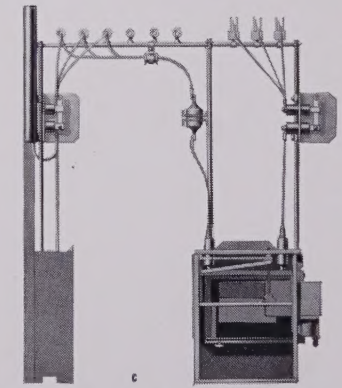

C.) Side view of installation B.

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ELECTRICAL ENGINEERING

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The Cover: The product cycle for step-type feeder voltage regulators such as the one shown has been materially reduced by the use of this new panel-type, steam-heated, core drying oven at Allis-Chalmers Manufacturing Company.

Allis-Chalmers photo

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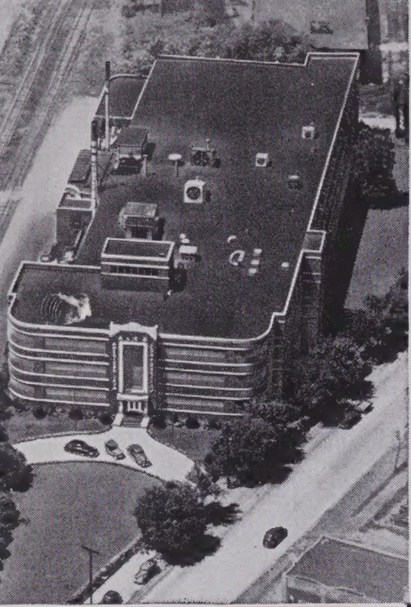

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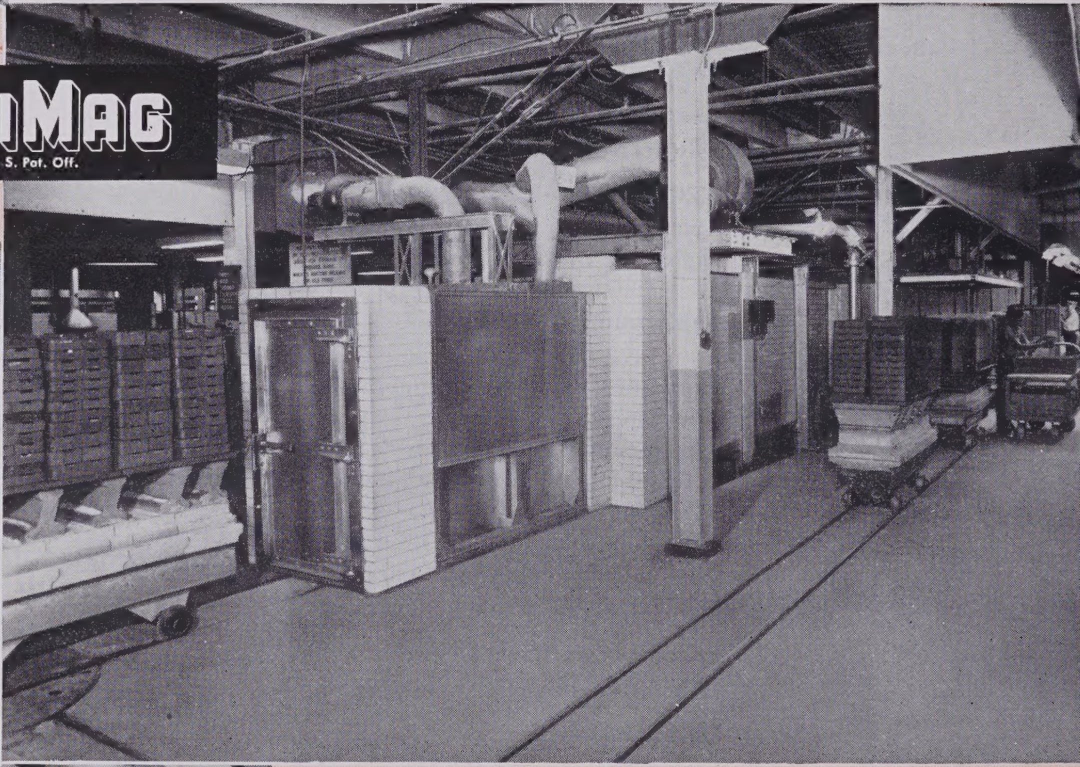

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Can Engineers Be Synchronized?

JAMES F. FAIRMAN
PRESIDENT AIEE

In the May 1947 issue of Electrical Engineering the Subcommittee on Professional Activities of the AIEE Committee on Planning and Co-Ordination published a summary of a report on "Organization of the Engineering Profession." The report indicated the great desire of AIEE members for greater unity of the engineering profession. President Fairman here indicates how such professional unity can be achieved.

CAN ENGINEERS be synchronized? Can they be persuaded to pull together, to co-operate, to pool their talents and resources in an orderly, organized effort to attain common objectives outside their several fields of specialized technology? In spite of appearances and experience to the contrary, many of us believe they can be so persuaded, and because we believe, we persist in our endeavor to find the right formula and to supply the requisite leadership. Those of us who participated in the discussions held at Section, District, and general meetings of the Institute some three years ago were tremendously encouraged by the interest and response of our own Institute members and by their evident willingness to relinquish some of the Institute's autonomy for the sake of forming an over-all organization of the engineering profession.

ACTION TAKEN

The questionnaires returned at those discussion meetings were summarized and conclusions drawn by our Professional Activities Subcommittee in a report published in the May 1947 issue of *Electrical Engineering* (*pages 496–501*). Since then, members have frequently asked what has been done about it. For the record, I answered that question at the Annual Meeting in Swampscott. The answer appears in *Electrical Engineering* for August 1949 (*page 693*). In brief, your Board of Directors referred the report to Engineers Joint Council; that body appointed a Committee on Unity to consider our report and other suggestions; the Committee on Unity recommended that an invitation be issued to 15 of the larger, national engineering societies to appoint representatives to an exploratory conference to be held in October; and the Council accepted this recommendation and issued the invitations.

To bring the answer up to date, your Board of Directors accepted the invitation and appointed Mr. Titus G. LeClair to be our representative. As chairman of the Professional Activities Subcommittee when our study was made, Mr. LeClair has the complete background and an intense interest in the problem. He also possesses to an unusual degree the personal qualities necessary for this assignment. We are fortunate that he is available and willing to undertake it.

It would be idle to speculate about the possible results of the exploratory conference. From a realistic but not at all pessimistic point of view, it is only another step on the road to better understanding among the several engineering societies and among their members which we hope will lead to greater unity of the engineering profession.

While pressing forward to that goal, we must not neglect the day to day problems which deserve our attention. We dare not let them wait on the perfection of an over-all organization. We can and we must work together with our brethren in other engineering societies on our common problems. Through such day to day co-operation, we shall not only take better care of our immediate concerns but we shall hasten the day when we shall attain that more perfect professional unity to which we aspire. Sometimes I wonder if we have put too much emphasis on the matter of organization on the assumption that if we could devise the right kind of organization all our problems would automatically be solved. Of course, this is not so. An organization is only a means to an end: an instrument or tool, by the use of which a group of people having common interests hope more readily to attain their objectives. We should look upon our organizations as tools. We should use them to their full capacities and by using them determine their limitations as well as their merits. We should modify them to meet new situations and we should scrap them when they are obsolete or worn out. Perhaps the difficulty lies not so much with our organiza-

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Essential substance of an address presented at the AIEE Pacific General Meeting, San Francisco, Calif., August 23–26, 1949.

James F. Fairman is Vice-President, Consolidated Edison Company of New York, Inc., New York, N. Y.

tions as with us. We seem to agree more fully on the problems to be solved than on the methods to be used in solving them. Our concern for the proper tools to be used may divert our attention from the job to be done and delay its execution. It may be that our societies become so identified with our sentiments and our prejudices that we are blind to their limitations and delay a much needed job of renovation or renewal. It may be that we are more concerned about who shall get the credit than we are about getting the job done.

There is work to be done. Why not use the tools at hand to the best of our ability? Why wait for a more perfect instrument before tackling the job? Why not work together, each using the means he prefers but being careful to use our skills and our chosen instruments in the common cause rather than to handicap or discredit the work of our brethren who happen to prefer different tools?

It seems to me there are two types of organizational tools available and ready for use. I shall refer to them in the same order in which they were discussed in our subcommittee's report. I refer to our old friends plans *B* and *C*.

PLAN *B*

Plan *B* called for the continuance of the present national engineering societies, such as the Institute, as autonomous organizations to cover their respective fields of engineering technology and for a separate, individual membership organization to take care of the nontechnological problems of the profession. There is an organization of this latter type, the National Society of Professional Engineers. Each of the component units of that organization, the local chapter, the state society, and the national society, is responsible for the activities in its own geographical sphere. Each is responsible to the individual member who has a direct voice in electing its officers and developing its policies.

The state society is not primarily a federation of local chapters but rather an organization of all the individual members of all the separate chapters in a state and is designed to handle state-wide problems beyond the scope of an individual chapter. Similarly, the national society is not only a federation of state societies but an organization of individual engineers designed to serve the profession on national problems which transcend state boundaries.

PLAN *C*

Plan *C* is based on the local engineering or technical societies council, of which an increasing number have been organized in recent years. A local council usually consists of representatives of the local units (chapters, sections, and so forth) of the several national engineering societies, to which may be added representatives of local engineering clubs and scientific or technical societies, either local or national in scope. A local council is not an organization of individual members but, as its name implies, a council of representatives from a number of completely autonomous societies. Its authority is limited to that specifically conferred upon it by the participating organizations. The individual members of the organizations represented on the council have no direct voice in its affairs. Its activities are necessarily local in scope, except as it may effect a working arrangement with other local councils in a state or region.

Ultimately these local councils may be grouped into state or regional councils and the state or regional councils into a national council. A national council, known as Engineers Joint Council, and consisting of representatives of five of the major national engineering societies including the Institute, has been functioning for several years and would logically be the nucleus around which plan *C* could develop.

These two tools are intended to serve the same purpose. They are relatively new tools and we are inexperienced in their use. Both can be improved. One may prove to be better for our purpose than the other. But each of us should use one or both of them now to the best of his ability rather than debate about their relative merits.

PLAN *D*

The essence of the over-all organization as proposed by the Institute's subcommittee in plan *D* is that it shall be of the individual membership type with the continuation of affiliated individual membership societies for specialized technical purposes only, the latter being the present national engineering societies which will continue to function in their respective technical fields and will have a voice in proportion to their membership in the affairs of the over-all organization. The individual members of the over-all organization may or may not be members of one or more of the affiliated technical societies and presumably an individual may be a member of one or more of the technical societies without being a member of the over-all organization. Members of the over-all organization will be members of the local and regional units of the over-all organization.

It is worthy of note that plan *D* combines the principal elements of plans *B* and *C*. Depending on one's point of view, plan *D* may be said to be either plan *B* or plan *C* with certain more or less desirable additions. On the questionnaire used by our committee at Section, District, and general meetings where the several plans were discussed, the most frequent comment was to the effect that plans *B* and *C* were only intermediate steps toward plan *D*. Some members favored plan *B* as an intermediate step, some favored plan *C*. A few suggested taking both steps in parallel to hasten the day when plan *D* might be made effective. Some were satisfied that plan *B* was all that was necessary, others were equally sure that plan *C* was the right answer but the larger number favored plan *D* as the ultimate solution to the problem of professional organization.

PATIENCE NEEDED

Can engineers be synchronized? In spite of this apparent diversity of opinion among the members of the Institute, my answer is still—yes; but it will be a gradual process. The fact that we must synchronize not only the members of the Institute but the members of other engineering societies means that it will take time. It will require patience, persistence, study, and above all, courtesy and good will.

We must exercise these qualities as individuals and as organizations. We must try to understand the other fellow's point of view, we must be willing to give and take, we must desire professional unity enough to make the sacrifices necessary to achieve it.

The Bell Computer, Model VI

E. G. ANDREWS

Controlled from remote stations, this new digital computer of the relay type reduces punched-tape instructions to a minimum. With novel control features similar to those used in recent automatic dial-telephone developments, this "upper-class" computer possesses six "intelligence levels." Subordinate levels are capable of solving problems such as complex-number multiplication without special guidance.

THE Bell Telephone Laboratories has placed in operation a new digital computer in its Murray Hill, N. J. building. It is called the Bell Computer, Model VI* because it is the sixth type of the seven relay computers designed and built by the Bell Laboratories. It includes the desirable features of its predecessors as originally conceived and placed into practice by Dr. George R. Stibitz and Samuel B. Williams. It also includes innovations that past experience and recent Bell Laboratory developments have shown to be desirable. Physical aspects, arithmetical aspects, principal usage, and unique and novel control features of the computer will be discussed in this article, with particular attention being given to the last item.

PHYSICAL ASPECTS

The Model VI computer consists of two principal parts: the remote control stations located in the quarters of the computing staffs, and the computing equipment located in another part of the building. A switchboard cable of the type used in telephone central offices is used to provide for the exchange of information between the two locations.

Figure 1 shows a remote control station. The three pieces of apparatus shown are types which are used extensively in teletype printer telegraph systems, with minor changes to adapt them to computer operation. The printer on the movable table records the answers to the problems; the hand perforator is used for perforating the data on the problem tapes; and the tape reader transmits the data for the problems to the computing equipment.

There are provisions for three of these remote control stations, although only two have been provided initially and one of these is used jointly as a test station and control station. The usual lock-out feature is provided to insure that one station cannot interfere with another that already may be in operation.

The computing-room contains 12 bays of equipment, consisting almost entirely of the heavy-duty-type relays used extensively in earlier computers and in telephone dial systems central office equipment. The frames have light grey enamel finish and other characteristics which make them resemble equipment that is found in the modern telephone office. There are about 4,300 relays, 86 cold-cathode tubes, and relatively small amounts of other miscellaneous apparatus used. As in the case of other Bell Telephone Laboratories computers, an indicator panel with approximately 600 small lamps is provided for showing the progress of various computing operations and for showing the numbers in various parts of the computer. It is illustrated in Figure 2.

This panel also has provisions for inserting instructions into the computing program on a manual basis where necessary to make corrections in programming. These facilities are used also for making tests under closely controlled conditions.

ARITHMETICAL ASPECTS

In any discussion about the arithmetical aspects of a computer, there usually are many questions about the detailed mechanization by which arithmetical operations are carried out. It is a phase of computer design and development which holds a maximum of fascination for the development engineer as well as for the interested scientist or mathematician. Therefore, even though there are no sensationally new arithmetical features in this computer, the changes do warrant mention. The range of numbers can be understood best by referring to Table I which compares number representations in the Model VI computer with those in the Model V computers installed at the Ballistic Research Laboratory at Aberdeen, Md., and at the Langley Field Laboratory of the National Advisory Committee on Aeronautics.

Table I. Comparison of Number Representations in Model VI and Model V Computers

Item of Comparison	Model VI Computer	Model V Computer
Number of digits for a number	3, 6, or 10	1, 2, 3, 4, 5, 6, or 7
Form of number notation for π, as an example	$+3.14159\ 2654\times10^{+00}$	$+0.3141\ 593\times10^{+01}$
Maximum number*	$\pm9.99999\ 9998\times10^{+19}$	$\pm0.9999\ 998\times10^{+19}$
Minimum number**	$\pm1.00\times10^{-19}$	$\pm0.1\times10^{-19}$

* The next higher number is the calculator's concept of infinity.

** The next lower number is the calculator's concept of zero. However, smaller numbers with the -19 exponent are possible with special problem coding.

By allowing only 3-, 6-, and 10-digit numbers to be intro-

---

* Previous Bell computers have not carried model numbers, but numbers that are now assigned to them in retrospect are

Model I.	Complex Number Computer
Model II.	Relay Interpolator[1]
Model III.	Ballistic Computer at Fort Bliss, Tex.[2]
Model IV.	Ballistic Computer at Naval Research Laboratory
Model V.	General Purpose Computers at Langley Field and Aberdeen[3, 4]

Essentially full text of a conference paper recommended by the AIEE Computing Devices Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Not scheduled for publication in AIEE *Transactions*.

E. G. Andrews is with the Bell Telephone Laboratories, New York, N. Y.

duced instead of any number of digits, some flexibility has been sacrificed in the Model VI, but it has been more than compensated for by the simplification in design detail. The new form of notation with the decimal point between the first and second digits has been introduced for two reasons: to simplify the isolation of the characteristic of logarithms, and to bring the notation into agreement with that now commonly used in expressing values in scientific literature. Heretofore, operators of our earlier computers were obliged to write, for example, the temperature coefficient of expansion of silver as 0.188×10^{-4} instead of the more usual 1.88×10^{-5}. This difference has been known to lead to confusion and errors in transcribing.

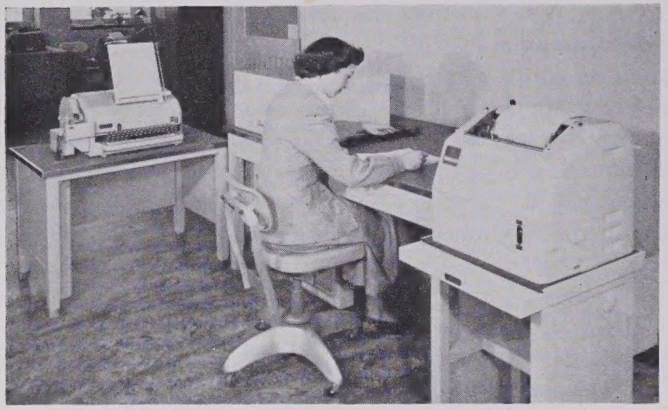

Figure 1. Remote control station equipment

Left to right: Hand perforator, attendant seated at operating table, and printer

It will be noted that the floating decimal point has been retained along with the power of 10 (exponent) range of +19 through to −19. The calculator performs all arithmetical operations, namely addition, subtraction, multiplication, division, and square root.

PRINCIPAL USAGE

When first conceived, the principal use of the Model VI computer was intended to be for performing the mathematical analysis of the characteristics of complicated networks of telephone and radio circuits, and for a relatively small amount of general purpose computing. Some types of network problems involved are computation of insertion characteristics of filters, equalizers, element deviation studies.

It is now contemplated, however, that a considerable portion of the computing will be on problems involving matrix calculations, including integral equations and solutions of simultaneous equations. Numerous problems are contemplated which require solution of differential equations, both ordinary and partial. Some table-making projects are desired, but they are likely to be deferred because of more urgent computations that will contribute more to the development projects immediately at hand.

UNIQUE AND NOVEL CONTROL FEATURES

The unique and novel control features introduced into this computer have been taken in part from recent developments in the automatic dial-telephone switching technique. But before enumerating these new features, it should be emphasized that the Model VI computer is as error proof as its immediate predecessors. Our engineers with justifiable pride still can say, "Starting with the Model III delivered to the Armed Forces in 1944, not one of our customers has reported their computers giving out a wrong answer as a result of a machine error." Also, before enumerating the new control features, reference will be made to Figure 3 which shows the relationship between the routine control circuit and the other computer components. They are fundamentally the same as for other Bell Telephone Laboratories computers. To solve a problem, operators perforate the problem data and computing instructions on a teletype tape. This is loaded into the tape reader at a remote control station. Computing starts when the operator depresses a start key at this station.

Initially the problem control circuit carries out certain conditioning operations as instructed on the tape, and then delegates control of computing operations to the central organ labelled "Routine Control." This component proceeds to control operations for computing or printing of answers and so forth, as directed by instructions from the tape.

The instruction on the tape may be in either of two forms. One provides all of the detailed computing instructions, and the other merely indicates which of the several sets of internal instructions is to be used. The first form usually will be used for types of problems that are encountered infrequently; the second, for types of problems that are expected to occur often. This will be discussed further in subsequent paragraphs.

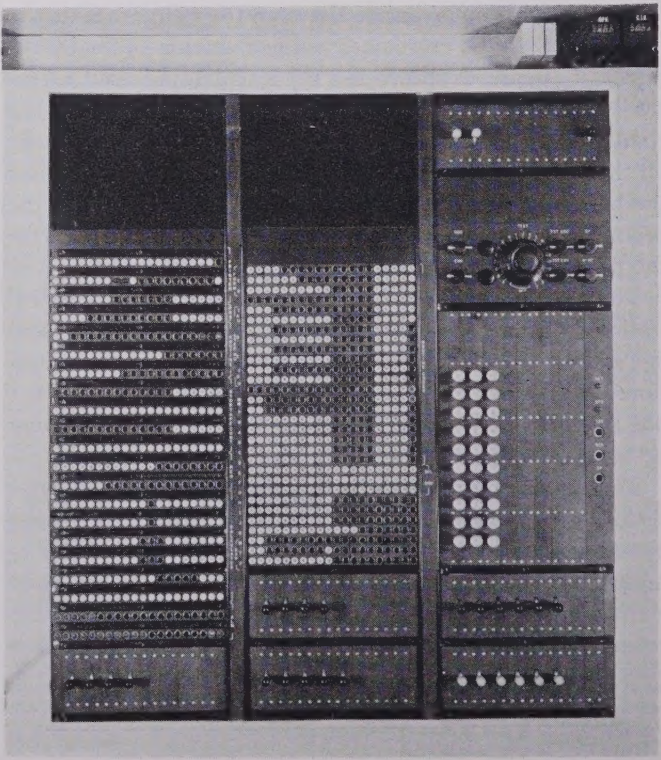

Figure 2. Indicator and test pane

The routine control circuit, in accordance with the instructions it receives, causes numbers to be passed from one register to another over the two 86-wire multiples or busses shown around the edge of Figure 3. When an arithmetical operation is required, the routine control designates the registers which hold the two numbers involved and directs the calculator to accept them and perform the desired arithmetical operation on them. The control circuit then indicates what disposition is to be made of the result in the calculator by designating the place to which it is to be transferred, that is, some particular register, the printer, or perforator. So much for general operating principles.

One of the new features is a "second trial" feature which is brought into operation automatically in almost all cases when the routine control circuit fails to receive the usual *OK* signal indicating satisfactory execution of the instruction, or operation, called for. Experience on previous computers showed that a sizable proportion of machine stoppages resulting from relay contact failures would clear themselves when the relay at fault operated again. It is expected, therefore, that this second-trial feature will make for longer periods of uninterrupted computer operation.

Another feature is the provision of two independently-controlled storage tapes. Special features are provided for simplifying the programming that normally would be required for handling problems involving simultaneous equations and certain kinds of vector and matrix multiplication problems.

Another new feature has been provided for the purpose of reducing programming time for those problems which involve numerous small and frequently used computing subcycles, as mentioned previously. These include finding the trigonometric function of an angle, obtaining the logarithm of a number, performing complex-number arithmetic problems, computations of the impedance and admittance for the various configurations of inductance, resistance, and capacitance, and so forth.

The practical and economical method of coping with this situation was to provide for built-in routines which could be called for in the programming at any time by some simple identification.

The device used for this purpose is a combination relay and electronic device which is used in the Automatic Message Accounting System in a modern telephone office. As used in telephone switching it consists of a large group of code points, each one corresponding to the location of the call-originating equipment of a subscriber. A signal on one of these code points denoting the origination of a call causes the circuit to ascertain and to record the subscriber's 4-digit directory number.

As used in the computer, the code points correspond to the computing operations in a subroutine. A signal on one of these code points causes the computer routine control circuit to set into operation the desired computer operation. A subroutine will use a train of from 6 to 20 of these code points in succession. Facilities are provided for 200 such subroutines, each being identified by the letter *A*, *B*, *C*, or *D* followed by a 2-digit number.

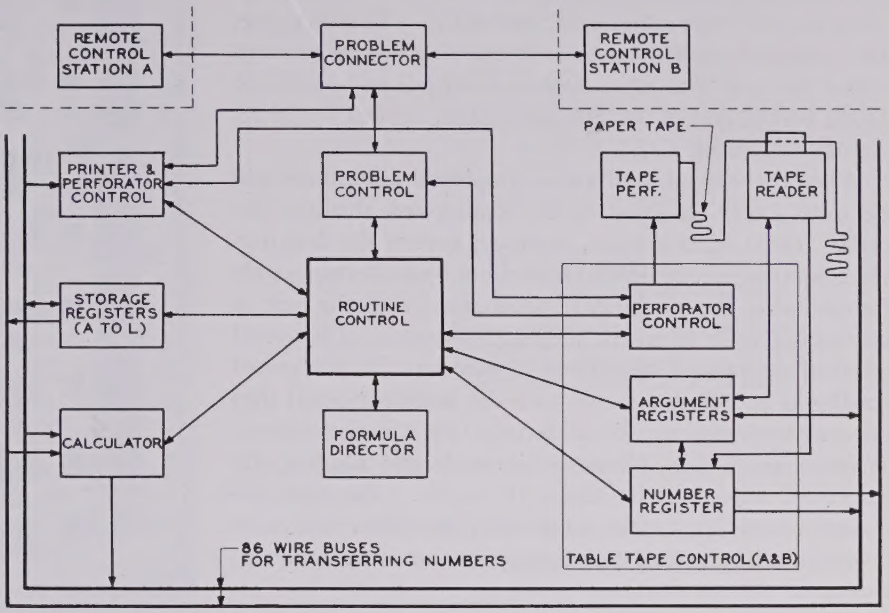

Figure 3. Block diagram of Model VI computer components

The operation will be explained by an example which assumes that computations have reached the stage where the product of two complex numbers is required. Table II shows the formula used and the coding of the individual computer operations. Figure 4 shows how the operations are made a part of the computer. It shows that there is an extremely close resemblance between the coding as it is written on paper and as it is memorized by the computer.

Table II. Coding of Subroutine for Complex-Number Multiplication

$$(A+jB)(C+jD)=(AC-BD)+j(AD+BC)$$

Instruction		
Number	Operation Code	Explanation of Code
1	$B \times D$ E	Multiply *B* by *D* and store in *E* storage register
2	$A \times C$ S	Multiply *A* by *C* and hold result in calculator
3	$S-E$ P	Subtract *BD* from *AC* to obtain real part of product and print result
4	$A \times D$ E	Multiply *A* by *D* and store in *E* register
5	$B \times C$ S	Multiply *B* by *C* and hold result in calculator
6	$S+E$ P	Add *AD* and *BC* to obtain imaginary part of product and print result

The operation numbers *1* to *6* correspond exactly with code points *1* to *6*. The letter designations correspond exactly with the coil designations. The letters which form a particular computing operation are associated together on the left by writing them together on one line, and on the right by running a single insulated cross-connection wire through coils having the same letter designations. This train of six operations would be identified by a subroutine number, such as *D36*, not shown in Figure 5. In practice these subroutine numbers are being called formula numbers. The *D36* subroutine would be called into the computing program with the order (operation code), *TD36*, which might be an order in some other subroutine, such as *C12*. In such a case, the computer control digresses in carrying out instructions called for by *C12* to allow *D36* to carry out its operations. Upon completion of the *D36* operations, control would return to subroutine *C12*.

When the 200 subroutines are employed fully, there will be over 2,000 insulated wires criss-crossed through the coils. These wires are not, however, part of the design of the computer, but are placed in position by those responsible for operating the machine, in accordance with the type of computing work in which they are engaged. The actual physical operations of placing a wire can be performed readily in one or two minutes by the same personnel that operates the machine. No soldering of the wires is required. When a particular subroutine is no longer needed, the associated wires can be removed readily. The time required to set up a new subroutine, therefore, compares favorably with the time of setting up the same instruction on tapes.

Figure 5 shows several of the coils with their associated cold-cathode tubes. Figure 6 diagrams the coil and tube-firing circuit.

A computer operation is initiated by causing a transient discharge from a resistance-capacitance-inductance network to be sent through the cross-connection wire. The system, consisting of the wire and the coil, behaves like a transformer with the wire acting as a loosely coupled 1-turn primary winding and the coil acting as the secondary. The transient through the primary induces enough voltage into the secondary to cause ionization between the control anode and the cathode of the type *313* cold-cathode tube. As soon as complete ionization takes place, a relay in the main anode circuit operates and disconnects itself from the tube, thereby allowing it to deionize. In this operation the tube is conducting for less than 0.01 second and is operating at conservative voltage limits. A very long tube life can be expected.

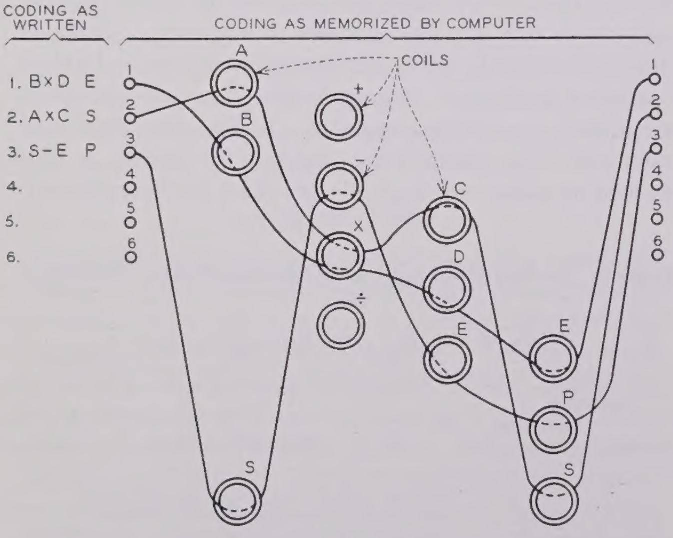

Figure 4. Wiring for subroutine for complex-number multiplication

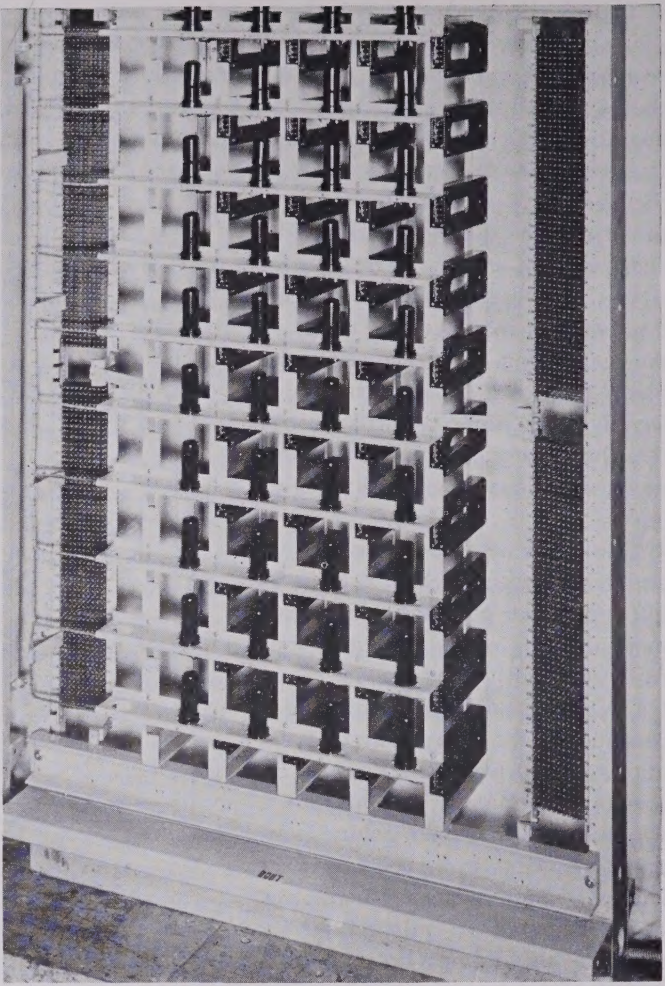

Figure 5. Mounting of coils with their associated cold-cathode tubes

The principal advantage to be derived from these internal routines is one of simplification of the programming. It provides bigger building blocks with which to build the complete program for solving a problem. At the same time the arrangement provides for faster operation through the use of electronics, permanent memory of the instructions, and much lower cost then would be entailed by attempting to use punched tape controls.

These larger building blocks presented a kind of a challenge to make the most efficient use of them. Indiscriminate use would make for chaos. An efficiency expert would systematize the situation by grouping together the subroutines which could be made complete in themselves and by grouping others so that they would have supervision over the first group. This is regimentation, but in a machine it is both acceptable and desirable. In fact, this regimentation is closely analogous to that which might exist in the most strict military school, where an upper classman would look with disdain upon any task (or computing operation) which a lower classman could perform. Consequently, the upper classmen would be assigned to perform the more complicated tasks according to their own skill and would be given authority to delegate lower classmen to do their more menial chores.

To continue the analogy, the Model VI computer has four levels of computing skill for making use of the internal subroutines already noted. They can be programmed to call in subroutines of a lower level and to regain control when the subordinate routine completes its task. The term "intelligence level" accurately describes the nature of these levels. (It is believed this term was originated by Dr. George R. Stibitz.)[5]

Figure 7 shows how this system operates in solving a rather complicated problem. One of the objectives of this problem is to determine the frequency response of the network. Mathematical analysis, therefore, is used in lieu of laboratory tests.

The top level of the flow chart in Figure 7 is designated *PT*, denoting "Problem Tape." While this tape is used primarily for the introduction of the parameters of the problem, it may contain as much detail in computing instructions as required. In the case of the problem being described, less than one inch of tape is required for the computing instructions, because the Model VI computer is assumed to have been taught already how to solve the ladder-network problem. The problem tape then simply specifies that subroutine *A12* be used. The tape thereby constitutes another intelligence level, higher than the four previously discussed.

In the interest of eliminating unnecessary detail, all of the changes in level are not shown in Figure 7, but there is still sufficient detail to show the principle of operation. By this systematic arrangement of internal routines, the labor involved in preparing the necessary problem data is near the irreducible minimum. The complete information for the ladder-network problem would be perforated out on a problem tape in accordance with the sequence shown in Table III.

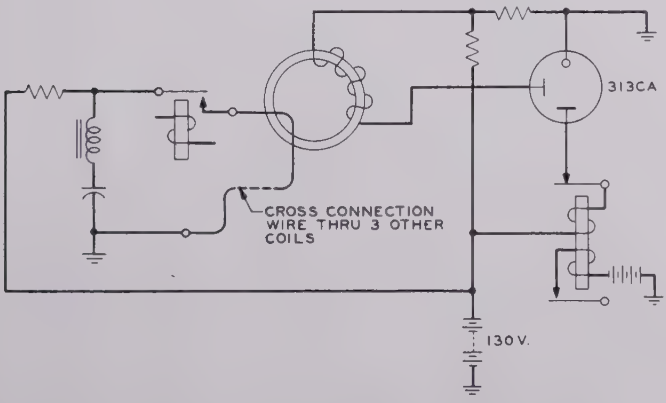

Figure 6. Schematic of coil and tube-firing circuit

Table III. Complete Data on Problem Tape for Network Problem of Figure 7

Item Number	Data on Problem Tape	Explanation of Data
1	Block 000	The designated location on the tape for the basic formula (or subroutine)
2	*A12*	Subroutine number for ladder network problem
3	Block 100	The designated location on the tape for f_1
4	f_1	
5	Block 101	The designated location on the tape for f_2
6	f_2	
7	Block 102	The designated location on the tape for f_3
8	*ENC*	A symbol (end of numbers check) denoting that no more frequencies are required for this problem
9	Block 200	The designated location on the tape for the parameters of the network
10	*C29*	Subroutine number for solving impedance Z_4
11	$R_1\ R_2\ R_3$ $C_1\ C_2\ C_3$ $L_1\ L_2\ L_3$	The values for the nine elements of impedance Z_4
12	*C37*	Subroutine number for solving impedance Z_3
13	$R_1\ C_1\ C_2$	The values for the three elements of impedance Z_3
14	*C41*	Subroutine number for solving for impedance Z_2
15	$R_1\ C_1\ L_1$	The values for the three elements of impedance Z_2
16	*C36*	Subroutine number for solving the impedance Z_1
17	$R_1\ C_1\ L_1$	The values for the three elements of impedance Z_1
18	*ENC*	A symbol (end of number check) denoting that there are no more parameters in this problem

The solution of the network is carried out in the following principal steps:

The *A12* routine assumes control at the start of the problem. It provides for organizing and setting up the initial conditions for computing the impedances for the various values of frequency *f*. It then delegates control to subroutine *B24*.

B24 controls the computation of the impedance of the various branches of the network. It also arranges to have the impedances recorded in block *400* on the storage tape for subsequent use by subroutine *B35*. After these preparations, *B24* will instruct the computer to use item 10 on the tape, that is, *C29*, as the subroutine number to use in computing the impedance of the first branch.

C29 provides for reading off the parameters, item 11, which follow and for combining the impedances for the individual elements, making use of *D*-level subroutine for the complex number arithmetic when required. The last instruction in *C29* is to instruct the computer to use the next number on the tape, item 12, as the next subroutine to use. Additional subroutines are employed as required. After computing the last impedance with values given in item 17, the computer is instructed to use the next number on the tape as a subroutine number. However, since item 18 is not a number but an *ENC* symbol denoting that there are no more parameters in this problem, control is restored to subroutine *B24*.

On regaining control, *B24* will instruct the computer to return to block *101*, item 5, on the tape to obtain the next value of frequency. *B24* then arranges to have the impedances for the next value of frequency recorded in block *401* and then, using this new frequency value, repeats all of the operations just described. After completing the computing with the last value of frequency, *B24* will instruct the computer to return to block *102*, item 7, for another value of frequency. However, since item 8 is not a number but an *ENC* symbol denoting that there are no more frequencies in this problem, control is restored to *A12*.

A12, on regaining control, will organize the computing of the complex values of voltage and current which the generator must supply. It then calls in *B35* to control these calculations.

B35 obtains access to block *400* which has all of the impedances for the first frequency value. It will call in *C*-level subroutines as required to carry out the computations and for printing the required data. *B35* will repeat for block *401*, *402*, and so forth, and will return control to *A12* after using the data in the last block in the *400* series.

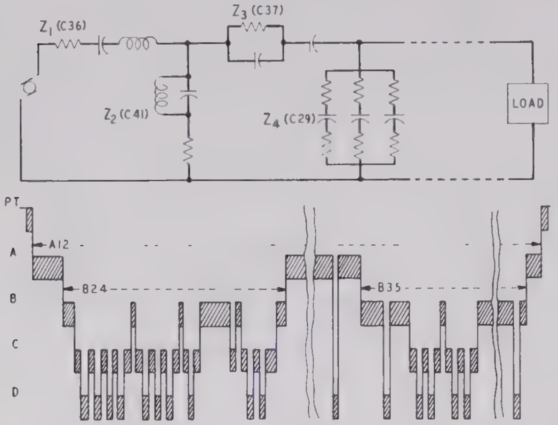

Figure 7. Time flow chart (below) showing use of four intelligence levels to solve a ladder-network problem (above)

A12, on regaining control, will provide for obtaining any additional information that may be required.

The preceding explanation pertains to a case where it is assumed that the problem data consist of 32 items of information, as summarized in Table IV.

Table IV. Summary of Information for Network Problem of Figure 7

Number of Items	Nature of Items	Number of Characters Perforated on Tape		
		Symbols	Data	Total
2	Frequency values		22	22
18	Problem parameters		210	210
5	Formula numbers		40	40
5	Block numbers	35		35
3	Start and end symbols	3		3
33	Total	38	272	310
		12 per cent	88 per cent	100 per cent

The first 25 of the 33 items in Table IV are associated intimately with the problem being solved. The last eight items are repeated for each problem. Thus, as stated earlier, it is believed that the labor involved in preparing the necessary problem data is near the irreducible minimum. Furthermore, the problem as described with 33 items is near the minimum in size. Ladder-network problems with 200 or more items of data are visualized. Subroutine *A12* would handle them all, regardless of the number, size, or complexity.

From the foregoing more or less detailed explanations, it will be noted that the individual computing operations specified by a subroutine consist mostly of a collection of calculator and recording instructions. It then follows that the calculator instructions themselves comprise an intelligence level below all of the others. Instead of being identified and called for by a subroutine number, the usual symbols +, −, ×, ÷, and √ are employed. As in the other intelligence levels, the calculator returns control to the higher level which called it in as soon as the prescribed arithmetical operation is completed.

The Model VI computer, then, has at least six intelligence levels shown in descending order of authority or control in Table V.

Table V. List of Intelligence Levels

Name	Designation or Symbol
1. Problem tape instructions	*SWR* (switch to routine)
2. *A* Subroutines	*A12*, and so forth
3. *B* Subroutines	*B24*, and so forth
4. *C* Subroutines	*C29*, and so forth
5. *D* Subroutines	*D59*, and so forth
6. Calculator instructions	+, −, ×, ÷, √

The Model VI computer will perform a series of computer operations involving almost any combination of the six levels by merely designating the 3-element code or the symbol of the kind shown in the last column of Table V. The code or symbol designated always will be one in the highest level used in solving the problem.

Further study reveals the fact that the 3-element code is so closely analogous to a symbol in this computer that it is proper to say that the Model VI computer responds to its own idea of a symbol for determining the logarithm of a number, a symbol for determining the tangent of an angle, and so forth.

The Model VI computer, therefore, represents a definite advance in computer design, because it is made to understand some of the symbolic language of mathematics and does not require that computing instructions be given in terms of minute details.

In concluding, reference is made to a pertinent remark made by one of the Bell Telephone Laboratories scientists several years ago, to the effect that large-scale computers are like very accurate but very dumb computresses because they require their supervisor to give them a computing program complete in every detail for each new assignment. But now with the Bell computer, Model VI, the large-scale computer has become an upper classman. It can be taught how to solve a problem. It can retain this know-how for use whenever called upon to solve this problem in the future.

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Armature Iron Losses in Series Motors

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IN AN A-C series motor, the flux pulsation in the field is predominantly at line frequency. The field iron loss can be computed easily and represented by a loss component in the magnetizing current. However, due to the rotation of the armature, the gap flux is rotating relative to the armature, as well as pulsating. The armature iron loss depends on both the line frequency and the speed. Part of the iron loss is supplied electrically by a loss component in the magnetizing current, while the remaining part is supplied mechanically as a load on the shaft. The accurate calculation of motor performance is dependent upon the correct determination and also the correct allocation of these losses.

MEASUREMENT OF LOSS

Actual measurements on one-third-horsepower motor show that the armature iron loss supplied electrically is independent of speed except near synchronous speed. If the iron loss is plotted against speed, the values drop quite suddenly at synchronous speed, as shown by the diagram of Figure 1.

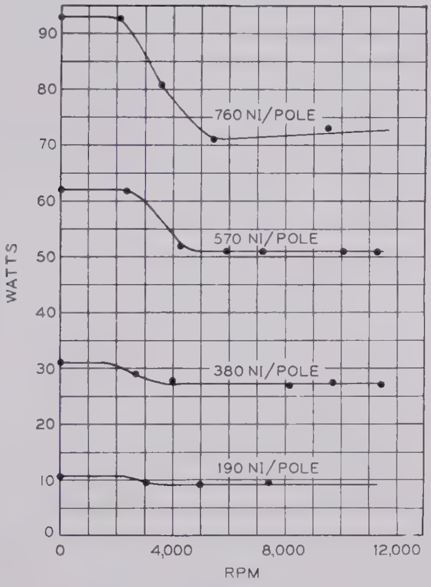

Figure 1. Effect of speed and excitation on field input

The mechanical load caused by armature iron loss can be separated from friction and windage losses. It increases gradually for speeds below and above synchronous speed. At synchronous speed the armature iron loss supplied mechanically increases sharply as shown in Figure 2. The increase in mechanically supplied iron loss just about compensates the decrease in electrically supplied iron loss. The total armature iron loss shows a gradual increase without discontinuity.

The foregoing phenomena can be satisfactorily explained quantitatively by the double revolving field theory. The gap flux is decomposed into two rotating flux systems. The effects of these systems are assumed to be independent of each other.

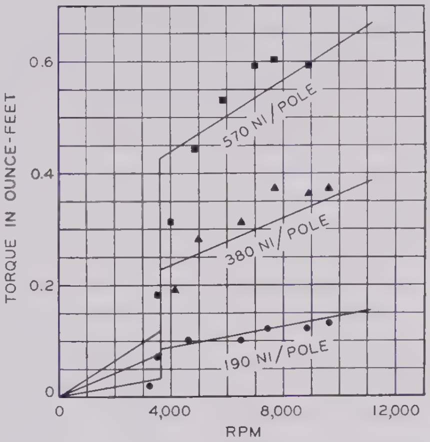

Figure 2. Magnetic drag on armature

Test values are indicated

The result of this analysis is as illustrated in the following:

1. At speeds below synchronous, the armature hysteresis loss is independent of speed and is supplied by the field. Above synchronous speed, the armature hysteresis loss is proportional to the speed and is supplied mechanically as a shaft load. The switching from electrical loss to mechanical loss at synchronous speed causes the observed discontinuity.
2. The armature eddy current loss increases with speed. At any speed, the field supplies the constant 60-cycle eddy current loss, while the rest is supplied mechanically. Both test results and calculations show that the mechanical load caused by armature iron loss is a very considerable factor. It amounts to about 15 per cent of the full load torque for a one-third-horsepower motor. This percentage is higher for smaller motors.

PRINCIPLE OF SUPERPOSITION

In relation to the art of electrical engineering in general, the foregoing facts furnish another example of the principle of superposition. The assumption of two separate flux systems is not strictly correct as the hysteresis effect cannot be described by a system of linear equations. Consequently the experimental results disagree with the theory in that the theory predicts a sudden change at synchronous speed, while the actual change really takes place in a range of a few hundred revolutions per minute about synchronous speed.

Digest of paper **49-70,** "Armature Iron Losses in Series Motors," recommended by the AIEE Rotating Machinery Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Lightning Investigation on a Rural System

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THE General Electric Company and the Central Electric Cooperative, Inc., at Parkers Landing, Pa., conducted an investigation on 7,200-volt multigrounded rural systems during the period from 1944 through 1947. All lightning measurements were made on one extensive feeder with approximately 465 miles of line and 1,350 distribution transformers protected by expulsion arresters.

Surge-current polarity and magnitude were measured with magnetic links having a measurable range of 100 to 30,000 amperes. Long-duration lightning surges were measured by automatic cathode-ray oscillographs having an initiation time of 20 to 50 microseconds. These instruments were designed to record times accurately within 0.5 millisecond. Sixty-cycle fault currents, arrester follow currents, load inrush, and magnetizing currents were measured by automatic magnetic oscillographs. Power currents in excess of a predetermined value through any one of the phase conductors or system neutral automatically initiated the magnetic oscillographs within one-half cycle.

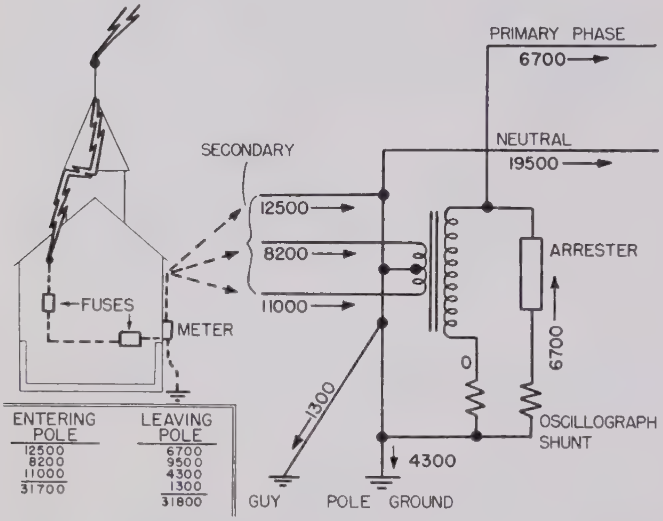

Figure 1. Path of stroke to church steeple and resulting surge currents at transformer pole

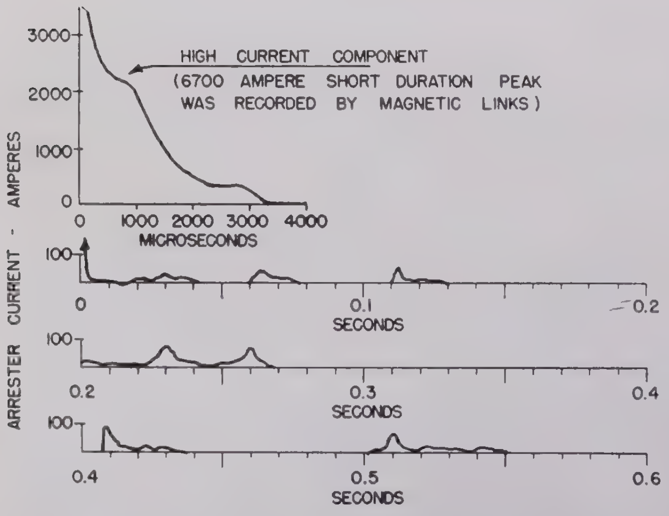

Figure 2. Replot of oscillogram showing long-duration arrester discharge resulting from stroke to church steeple

In a representative 8.5-mile section of line, a study was made in which magnetic links were installed on every conductor connected to each of the transformers (see Figure 1) and pole ground wires at adjacent poles. Cathode-ray oscillographs were installed at several of the transformers in this section. In 88 transformer-years, a total of 120 lightning surges reached the transformers, resulting in 86 arrester discharges. One-third of the surges arrived at the distribution transformers by the secondary or pole ground wires; about two-thirds reached the system phase and neutral conductors from the secondary and pole ground wires.

The most severe lightning surge of the 17 recorded by automatic cathode-ray oscillographs was obtained when lightning struck a church steeple and entered the system by way of the secondary conductors. The surge distribution is shown by the magnetic-link records, and the arrows show the direction of negative current flow, Figure 1. The automatic cathode-ray oscillograph at this location was connected to record both the primary transformer and arrester currents. No surge was recorded in the transformer primary. The oscillogram of the arrester discharge, Figure 2, shows a current peak of 3,500 amperes that decayed to virtual zero in 3,000 microseconds. This was followed by six separate long-duration discharges of 90 amperes or less that ceased after 0.55 second.

A representative group of expulsion arresters equipped with magnetic links was selected for inspection after each lightning storm to minimize superposition of records. Data from 293 arrester-years' experience at these locations indicate lightning surges often caused simultaneous discharges of arresters at adjacent locations. One severe surge discharged all 13 arresters on three miles of line. Arrester discharge rates vary greatly with the locality. Magnetic links show that 40 per cent of the arresters discharged once per year, 19 per cent twice per year, 6.5 per cent three times per year, and 2.7 per cent four or more times per year. The arresters average 1.1 discharges per year. On a yearly basis, 0.36 per cent of all arresters on this feeder discharged currents exceeding 30,000 amperes, 50 per cent at least 200 amperes, and 67 per cent at least 100 amperes.

Digest of paper **49-110**, "Lightning Investigation on a Rural Distribution System," recommended by the AIEE Protective Devices and Transmission and Distribution Committees, and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Is There a Doctor in the House?

Unsolved Motor Design Problems Suggested for Postgraduate Theses

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ONE SOMETIMES HEARS the statement that the electric machinery field is so well established that relatively few opportunities exist for further investigations and developments. Nothing could be further from the truth. In the electric motor business alone, many problems appear which are not solved rigorously but are by-passed by estimates based on experienced judgment; or they are solved by empirical data in use in design offices, but not generally available in the literature. In either case, further study is justified.

Under pressure of business, many of these problems remain partially or completely unsolved. In the meantime, staff members in our engineering colleges may be seeking subjects for suitable masters' and doctors' theses. A list of such problems is given here. It is hoped that the possibility of the solutions to these problems proving useful will not count too heavily against them. These investigations may require anywhere from 100 hours to 100,000 hours.

The chief engineers of four motor manufacturers point out problems which are largely unsolved, or might justify further investigations. They are suggested as postgraduate theses for students interested in electric machines.

Before going into detail on such problems, the writers would like to point out an entire field which remains largely unexplored. Many of the data available on machinery involve *analysis*. That is, a machine is presumed to be fixed and the problem is: To determine the parameters by either test or design data, and to use the parameters to obtain the performance by graphical or calculated means. To repeat, this is analysis.

Distinct from such problems are those of *synthesis*. In such cases, the desired performance is known, and the problem is to determine certain attributes of either the electric or magnetic circuit required to yield the performance. Direct methods of electrical design involve true synthesis.

With comparatively few exceptions[1–4] this whole field is largely unexplored. Although synthesis is most useful in a design office, it is not at all necessary for one to be an electrical designer to make contributions to this field. Developments of this sort involve expansions and transformations of existing analyses, while not always requiring design judgment.

Opportunities and problems in motor synthesis are too many to be listed in detail. Some of them are pointed out in the following, along with the suggested analyses.

POLYPHASE MOTORS

Two-Speed Winding Constants. Many 2-speed polyphase induction motors are built in which the second speed is obtained through reconnection of the same stator coils for twice the number of poles. This is the so-called consequent pole winding. What are the correct values of leakage* and magnetizing reactances for both connections? How do the no-load currents and core losses vary with reconnection? There is some evidence that standard methods of calculation, adjusted for these conditions, are not rigorous enough to be completely trustworthy. Various methods are in common use for determining the equivalent heating effect of periodic loads. Why not obtain experimental verification of the temperature rise on polyphase motors when operating on special duty cycles, including frequent starting, stopping, plugging, and reversing?[5–12]

Material can be found in textbooks concerning the use of polyphase induction motors as asynchronous generators. Yet when one occasionally uses such a machine as a calibrated load in laboratory tests, there are some doubts as to the nature of the losses and the supply for the core loss. Is the surface loss supplied by the same source as the rest of the iron loss? Investigation of the wound-rotor induction motor as an asynchronous generator, and as a frequency changer, should prove useful also; the separation of core losses and the supply for the components of core losses seems to be in some doubt for the latter machine.

The predetermination of temperature rise in motors is a difficult or almost impossible task. However, the correlation between hot-spot temperature rise, rise by thermocouple, and rise by resistance as determined experimentally is still a problem which could stand further investigation. This could cover nonventilated and single-end and double-end ventilated machines.[13–18]

Breakdown torque, locked kilovolt-amperes per horsepower, and the slip of polyphase motors are all interrelated through the same group of parameters. Curve sheets show-

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* See series of papers on leakage reactance presented at AIEE Middle Eastern District Meeting, Dayton, Ohio, September 23–25, 1947, and listed on meeting program, (*ElE, Sept '47, page 929*).

ing the relationship are comparatively simple if the approximate circuit is used. But what are the more exact relationships and what about the effect of saturation on the locked kilovolt-amperes? A series of charts for such analyses might be useful.

Can any quick method be developed for determining the effect of unbalanced voltages on the performance of polyphase induction motors?

SINGLE-PHASE MOTORS

Leakage Reactance. (*a*). Assume a stator winding is built in a field with exceptionally wide teeth. The leakage reactance can be calculated in the usual manner.* (*b*). Assume now that an equal member of stator slots is provided between each existing slot in (*a*). These contain no winding. Will the leakage reactance be different in (*a*) and (*b*)?

(*c*). Presume now that a start winding (say for split phase) is added only in the intermediate slots of (*b*). When this winding is excited during the starting period will it modify the reactance of the initial main winding? Through affecting the zigzag flux? If so, it implies that the main winding leakage reactance is different when the start winding is active, from that used for running performance. What are the two values under these circumstances?

Concentrated Windings. Methods of calculating the leakage and magnetizing reactances of distributed-type concentric windings are available.[19] However, if the main and start windings each reduce to one concentrated coil per pole, the calculations do not seem to be rigorously accurate. What is a good system for calculating these reactances under such conditions? Are the discrepancies in performance due to the "block"-shaped air-gap flux, and resulting harmonic reactions?

Suppose now instead of a separate coil for each pole on the main winding, one coil is looped half way around each pole, forming a skein winding. That is, one continuous coil supplies all of the main and a similarly shaped coil supplies all of the start winding. How are the winding parameters calculated? How can one predict the reduced torques and horsepower ratings resulting from these windings as compared to normally distributed types?

Comparisons. The following comparisons are for single and polyphase motors.

1. A single-phase motor is built in exactly the same stator and rotor laminations and with the same stack and rotor cage as a polyphase motor. Suppose each is designed with the same flux per pole. What are the relative values of maximum torque obtained from each? (Some assumptions must be made concerning relative conductor length and winding factors.) On the basis of these maximum torques, what relative horsepower ratings should be assigned to each?

Because of the increased magnetizing currents of single-phase motors, the circular mils per ampere of the two will differ. On the basis of equal copper loading in both, what full-load horsepower ratings should be assigned to each?

2. Suppose the foregoing single-phase motors were built as capacitor-start induction-run types. Does good design result from the use of the same rotor resistances in both cases? If not, what should be the relative resistances of squirrel cages for single and polyphase motors built in the same laminations and stacks?

3. It seems to be accepted as more or less axiomatic that double-layer lap windings are best for polyphase and concentric type are best for single-phase motors. For single-phase motors what are the relative merits of concentric and lap windings? This could be investigated on the bases of relative winding parameters, copper weights, and resulting performance.

SPECIAL TYPES OF SINGLE-PHASE MOTORS

Capacitor Start. The application of electrolytic capacitors to motor starting duty involves the voltage drop across the capacitor. Starting performance of such motors is subject to analysis and synthesis.[20] The torques and currents during the acceleration of such a motor normally are not calculated because of the tedious operations involved. But at some value of speed, (say two-thirds of synchronous) just before the centrifugal switch opens, is the voltage across the capacitor higher or lower than at starting? Can any rule governing the combinations or ratios of all the winding parameters be worked out so that by a simple check it is possible to determine the relative value of the voltage drop across the capacitor at two-thirds of synchronous speed? (Excessive voltage drop at these speeds may reduce capacitor life.)

Is it possible to calculate a combination of "critical" motor winding parameters, below which the accelerating *torque* of such a motor at two-thirds speed is less than the starting value? Or conversely, if the combination of parameters is above the "critical," is the accelerating torque always sure to be higher than the stalled torque?

Accelerating Torque—Split-Phase Motors. The torque of a resistance split-phase motor at any speed can be calculated, but the method is tedious. Is it possible to set up simple equations or curves involving all of the winding parameters which show whether the torque at two-thirds synchronous speed is higher or lower than the starting torque?

Repulsion Induction Motors. Calculations for the performance of single-phase repulsion induction motors take into account the brush shift. Why not an experimental verification of the performance with various shifts? What about the effect of brush and commutator bar width on the apparent shift?[21]

The Shaded-Pole Motor. This is in a class by itself. While millions of them are produced each year in hundreds of different designs, its habits are less understood than those of the dodo bird.

Pioneering work on analyses has been done by one[22,23] of our writers, but much remains to be done. The machine parameters are not subject to rigorous calculation in an entirely satisfactory manner. Losses cannot be calculated with assurance. Designs are made by extensive experimental work, varying pole shapes, degrees of shading, sizes of shading coils, air-gap lengths, and rotor resistances. Weights, shapes, and locations of magnetic wedges introduce additional diabolical factors. Direct design syntheses are totally lacking.

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* See footnote, page 759.

So many combinations of factors are possible with all of the variables to adjust, that investigations are very complicated. Are there various new equivalent circuits possible for the shaded-pole motor, and if so, should they be doubly fed? Can any analyses hope to be accurate without considering several harmonics in the air gap flux?

The entire field is wide open for research.

LOW-VOLTAGE SUPPLY TAP

Many motors, both fractional-horsepower and integral-horsepower, are made with a winding which gives a low output voltage for a small amount of electric power to operate a relay switch or lamp. This is sometimes simply a pair of taps from the main motor winding and sometimes a separate winding.

At first thought it appears to be a simple transformer or autotransformer problem to determine the output voltage and regulation. However, the actual cases are far from simple. The voltage and regulation are affected by the size of the motor compared to the tap load; whether the motor is split-phase, polyphase, capacitor, or repulsion; the voltage of the motor; and many other conditions such as exact location of taps, size of air gap, eccentricity of air gap, and many unknown factors.

The designer would like to be able to predict accurately the open circuit and load voltages and would like to know all the factors affecting them.

UNEXCITED SYNCHRONOUS MOTOR

Reluctance Types—Torques. The reluctance-type synchronous motor was analyzed in part by Ball[24] using a method based on energy stored in a magnetic field. Results cannot be verified consistently by test. The 2-reaction theory with excitation reduced to zero[25] represents an analysis with considerable promise.

Methods of predicting pull-out torque and running performance of reluctance-type synchronous motors would be very useful and could stand further investigations. In addition, the whole question of *synthesis* on such motors remains totally unexplored. Given a fixed magnetic circuit, how many stator conductors are needed to produce a desired pull-out torque? This would be the approach for synthesis. Suppose the field is excited by polyphase, by plain single-phase action, or by permanent split capacitor windings? Synthesis for the first case is not too difficult. The other cases are probably very complicated.

For loads of high inertia, the size of a reluctance-type synchronous motor frequently is fixed by the pull-in rather than the running torque. How can the synchronizing or pull-in torque of all of the foregoing types of synchronous motors be calculated for a given load inertia? For the conventional, excited case, the differential equations governing these conditions have been set up on the differential analyzer. Perhaps a similar investigation could be made with the unexcited motors.

Hysteresis Type—Synchronous Motors. With few exceptions[26,27] little can be found in the literature on these motors. They are being produced. Analyses pertaining to every item of performance would be useful. The metallurgy of the rotor material is vitally important.

Direct design methods are totally lacking. A few empirical rules and extensive experimental work are the present means for making new designs and ratings.

D-C MOTORS

Contrary to the general understanding of many, d-c motors are not declining in importance or usefulness. The usefulness of the d-c motor as a means of securing adjustable speed and the value of adjustable speed to industry account largely for the continued popularity of d-c motors.

In this connection, d-c motors are being used with grid-controlled rectifiers supplying unidirectional current from a-c circuits. Depending upon the number of phases used in the rectifier conversion, the instantaneous voltage applied to the motor terminals varies over wide extremes. The resulting motor performance and characteristics are substantially different than when supplied from true d-c sources. Iron losses, copper losses, and stray losses may differ radically from those present under the equivalent condition with a d-c source.

Analysis of the flux conditions and the current loading of conductors of a d-c motor operating from single- and multiple-phase rectifier sources is deserving of attention.

UNIVERSAL OR SERIES MOTORS

Millions of universal motors (or motor parts) are built for the domestic, commercial, and portable tool fields. Is there no way in which rigorous analyses of their operation can be made so that tests and calculations agree? Or, if this step can be accomplished, how about a direct design method whereby required performance can be met? Or, as just a part of the problem, how can one calculate the magnetization curve for such a motor which actually will agree with the apparent magnetization curve shown by performance? How does the effect of commutation interfere with performance, and how can it be calculated? The literature on these subjects is very inadequate.

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Electrical Essays

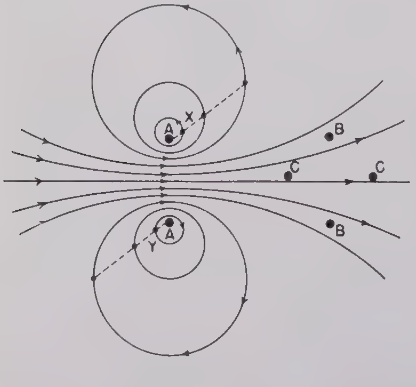
Magnetic Control of Mutual Induction

Electrical engineers at the company where I work tell me that one coil acts inductively on another if some of the magnetic lines which link the first coil also link the second coil, and they tell me that if there are no magnetic lines which link both coils, then there cannot be any mutual induction between the coils.

In Figure 1 then, a coil, *A*, carrying current and producing magnetic lines will act inductively on a coil in position *B*, but not on a coil in position *C*.

Now I have found a way of sweeping away these magnetic lines coming from *A* so that they will not even come near coils *B* or *C*, and therefore certainly cannot link them.

I got this idea standing in front of a fan on a hot day last week. In the room, I could feel the air from the fan more than ten feet away. However, I know that if I took the fan outside, and stood in a high wind, I would have to get up real close before any of the air from the fan would reach me.



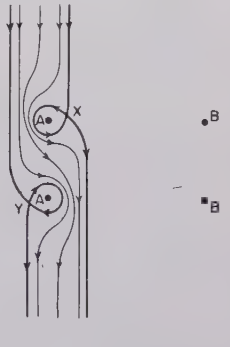


Figure 1 (left). Magnetic lines of coil A

Figure 2 (right). Deflection of magnetic lines linking a coil

Now we do the same for a coil, and the magnetic lines which it puts out, only of course I do not use wind to blow the magnetic lines away.

What I do is use a good strong magnetic field coming from some other coil or magnet to push away the magnetic lines linking *A* so that they will not link *B*.

In my figures I make this strong magnetic field come in vertically downwards in the plane of the paper. If we look back at Figure 1 we see that we can find points such as *X* near the upper side of coil *A* where the lines from *A* point straight upwards. At these various points *X*, the field strength itself is strong near the coil side, and is weak for *X* far from the coil side.

If now I bring in my constant vertical field *H*, acting downwards, it will reverse the field at the points *X* which are farther away from *A*, but it will not be strong enough to reverse the field at points *X* near to *A*. There will be one *X* point therefore where the field strength will be reduced exactly to zero, and at that point there will be a singularity, where the magnetic line crosses itself. I show that in Figure 2.

Similarly, as I show in Figure 2, there will be a point *Y* near the lower side of coil *A* where the magnetic line crosses itself.

Now all the other magnetic lines which link *A* will lie between the two lines *X*, and *Y*. I show a few of these lines drawn light in Figure 2. Thus, there are no lines linking A which also link B. All such lines shown in Figure 1 are as it were blown down by the impressed constant field H so as to miss B completely. Thus mutual electromagnetic induction between A and B is completely stopped.

I have two questions for my readers:

1. Is my invention of how to stop mutual induction

between coils any good? 2. If so, what is this invention good for?

J. Slepian, Alter Ego

J. SLEPIAN (F '27)

(Associate Director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Two Boxes

In the land of pure electrical constants an engineer is investigating two boxes, each having four terminals. Two of the terminals on each box are marked "input," and the other two "output." The engineer connects the input terminals to a source of alternating current (pure sine wave) and notes that the performance of the two boxes at the output terminals is the same for similar external loading. He also notes that the efficiency of both boxes is 100 per cent for all power loadings. However, the input currents of the two boxes differ remarkably. He tabulates his readings in Table I. The voltages and currents are expressed in unit values so that the reader may select his own base in studying the performance of the two boxes. What is in the boxes?

Table I

Input Volts	Input Current Box Number 1	Input Current Box Number 2	Watts	Output Volts	Output Current
Unity power factor load:					
1.000	0.000	1.000	0.000	1.000	0.000
1.000	0.259	0.966	0.250	0.966	0.259
1.000	0.500	0.866	0.433	0.866	0.500
1.000	0.707	0.707	0.500	0.707	0.707
1.000	0.866	0.500	0.433	0.500	0.866
1.000	0.966	0.259	0.250	0.259	0.966
1.000	1.000	0.000	0.000	0.000	1.000
Zero power factor load:					
1.000	0.000	1.000	0.000	1.000	0.000
1.000	0.250	0.750	0.000	0.750	0.250
1.000	0.500	0.500	0.000	0.500	0.500
1.000	0.750	0.250	0.000	0.250	0.750
1.000	1.000	0.000	0.000	0.000	1.000

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Answers to Previous Essays

Electromagnetic Induction Intensifier. The following is the author's answer to a previously published essay of the foregoing title (*EE, Aug '49, pp 677–8*).

My Alter Ego, the inventor, has quite surpassed himself this time, but he is only carrying on with logical completeness ideas concerning magnetic lines which are held and adhered to by many engineers.

To begin with, the spiraling lines of magnetic force are no new discovery of the inventor, but occur all the time. It is only in the exceptional case, as for the perfectly flat plane coil that the magnetic lines close. Twist this flat coil ever so slightly out of the plane, and the magnetic lines will spiral around endlessly, never closing. The answer (*EE, Feb '48, p 187*) to the electrical essay, "Magnetic Field of a Solenoid," (*EE, Jan '48, p 58*) indicated that for a long solenoid, too, the magnetic lines also spiral endlessly.

For Faraday, who introduced them, the electric and magnetic lines of force were very real things. For Faraday a magnetic line probably had substantiality and individuality equal to that of a stretched string. Maxwell in his famous Treatise, attempted, and quite successfully, to put Faraday's ideas into mathematical form. However, and this is one of the great values of a mathematical treatment, when Faraday's (and Maxwell's) ideas were reduced to mathematical equations, the properties and connotations of lines of force which were irrelevant to electromagnetic phenomena disappeared, and only that which was essential remained. Gone were the threads, the electric and magnetic lines, which joined remote points in space, or formed nicely stretched out loops, and which might be considered as moving about "cutting" wires. What was left was only the vital essence, the vector field: at each point of space, a direction, and a magnitude.

Maxwell's equations deal only with vectors, and these vectors are wholly and completely the electromagnetic field according to Maxwell. You may if you like introduce lines of force to help visualize the vector field, but properties of lines of force specific to curves in space and not significant for vector fields, also will be irrelevant and nonsignificant for electromagnetic theory.

The only significant properties of the lines of force for electromagnetic theory will be their direction and their density, in a sufficiently local region, since these properties are the only ones which correspond to the properties of the vector field. The continuity and individuality of the lines will be irrelevant properties. We may break them off in any small region, as we please, and start off new lines with similar direction and density, and these broken lines will represent the essential properties of the vector field just as well as the continuous lines.

Whether any particular line closes or not, and whether it links one or more particular metallic circuits will be irrelevant, since these two properties of lines depend on the lines having continuity and individuality, which we have just observed to be irrelevant. The present essay illustrates the irrelevance of the first property, and my next essay will illustrate the irrelevance of the second property.

That particular one of Maxwell's equations which expresses Faraday's law of electromagnetic induction is

$$\text{Curl } \boldsymbol{E} = -\frac{c}{4\pi}\frac{\partial \boldsymbol{B}}{\partial t} \qquad (1)$$

It has in it only $\boldsymbol{E}$ and $\boldsymbol{B}$, both vectors. There is nothing about lines of force in it. The integral equivalent of equation 1 is

$$\int \boldsymbol{E}_s ds = \frac{\partial}{\partial t}\int\int \boldsymbol{B}_n dS \qquad (2)$$

The left-hand member, $\boldsymbol{E}$, integrated around any closed path which may be a metallic circuit in particular is called the induced electromotive force or the induced voltage;

E, in this essay. The integral on the right is to be carried out over a 2-sided surface bounded by the closed path or circuit. How such a 2-sided surface looks for a multiturn coil was discussed in the preceding electrical essay, "Faraday's Law of Induction II" (*EE, Jul '49, p 613*). This integral is frequently and quite properly called the flux-linkage of the bounding circuit. It is independent of the choice of 2-sided surface bounded by the circuit. Flux-linkage defined by this integral is a definition in terms of the circuit, which determines the choice of surface over which to integrate, and of the vector-field flux-density. It has no irrelevant elements.

The 2-sided surface bounded by the smooth closed curve, over which the surface integral is taken in equation 2 is of some complexity when the bounding curve follows the wire in a multiturn coil. This was the subject of the preceding electrical essay. In this case, for the usual compact coil, we make little error if we substitute for the single 2-sided *n*-sheeted surface with *n*-1 branch-points, a set of *n* independent 2-sided single-sheeted surfaces, each such sheet being almost bounded by a not quite closed turn of the coil.

Similarly, the magnetic lines for a usual multiturn coil form a configuration of some complexity, each line spiraling around endlessly. Here again, we may make a small deviation from the actual field portrayed, if we force each line to close when it next comes back near itself. The lines of force then become simple closed curves whose density and direction approximately correspond to the magnitude and direction at each point of the actual vector field being portrayed.

It is when such approximations as have been just described in the preceding two paragraphs are valid, and it is when such approximations are used, that the method of calculating flux-linkage used by my Alter Ego and his friends, the engineers, is equivalent to the flux-linkage defined by the surface integral in equation 2. Certainly such approximations are valid for the individual usual compact coils which are used in electric machines. However, many of the magnetic lines would not even approximately close for a configuration of coils like that in Figure 4.

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Low-Voltage Winding. The following is the author's answer to a previously published essay of the preceding title (*EE, Aug '49, p 678*).

The main transformer winding will have two components of current in each half. For its excitation it will draw one ampere fundamental and 0.4 ampere third harmonic. This will be one component in each half of the winding. For the teaser transformer 86.6 per cent of rated voltage is applied to 86.6 per cent of the winding, hence its core operates at normal flux density. The exciting magnetomotive force must be equal to that required when the full winding was excited. As a result in the *T* connection the teaser transformer draws $1 \div 0.866 = 1.15$ ampere fundamental and $0.4 \div 0.866 = 0.46$ ampere third harmonic. This represents the total current in the teaser transformer. It has an rms value of $\sqrt{(1.15)^2+(0.46)^2}=1.24$ ampere.

The teaser transformer exciting current divides equally between the two halves of the main transformer, hence it introduces a fundamental component of $1.15 \div 2 = 0.577$ ampere and a third harmonic component of $0.46 \div 2 = 0.23$ ampere in each half. In one half, the fundamental component adds at 90 degrees to the other fundamental component there. In the other half the components subtract at 90 degrees. In either half the magnitude of the resultant fundamental component is $\sqrt{1^2+(0.577)^2}=1.15$ ampere. In one half of the main transformer winding the third harmonic component from the teaser transformer adds at 3×90 degrees $= 270$ degrees, to the other third harmonic component there. In the other half the components subtract at 270 degrees. In either half the magnitude of the resultant third harmonic component is $\sqrt{(0.4)^2+(0.23)^2}=0.46$ ampere. Since both halves of the winding carry equal components their rms currents are each $\sqrt{(1.15)^2+(0.46)^2}=1.24$ ampere. Thus we find that the three line currents have equal rms values. However, their wave forms are dissimilar because the harmonic components in each case are not in identical positions with respect to the fundamental components.

An unusual thing about this circuit is that it is a 3-phase circuit having equal third harmonic currents in the lines. This is possible because the currents are 120 degrees apart on the harmonic time scale and add to zero. The currents are only 120 degrees $\div 3 = 40$ degrees apart on the fundamental time scale, and not 120 degrees apart as they would have to be to make the line current wave forms identical.

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Cathodic Vacuum Etching

A Ford Motor Company (Dearborn, Mich.) physicist, using a process called cathodic vacuum etching, prepares a metal sample for microscopic examination. Ions of low-pressure argon gas, which have been charged by 12,000 volts of electricity, bombard the metal, etching out extremely minute details of the surface structure

Cable Impregnated With High-Viscosity Oil

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DURING 1941, a 7-mile circuit of 120-kv high-pressure gas-filled pipe-type cable known as the *SMD*-type cable was installed by The Detroit Edison Company, and has been in satisfactory operation since it was energized on December 31, 1941. An impregnating compound of much higher viscosity than that normally used in the mass-impregnation of cables was employed, and, at the time, preimpregnation of the tapes seemed to be the only method of assuring satisfactory impregnation throughout the wall of insulation.

A 12.3-mile circuit of *SMD*-type cable has been installed since at Detroit and was energized on December 13, 1948. At the time the design for this new line was being studied, mass-impregnation of the insulation was investigated and, as a result, half of the cable on this line has been made with mass-impregnation.

In conjunction with the question of mass-impregnation versus preimpregnation, it was necessary to consider two chief problems. One was whether satisfactory impregnation could be achieved by the mass-impregnation process when a thick wall of insulation was to be impregnated with an oil of 3,000 Saybolt Universal seconds (6 poises) at 100 degrees centigrade. The other was whether, in a mass-impregnated cable, proper gas pressure could be assured at all locations in the insulation to prevent ionization at operating voltage if, for instance, rapid cooling of the cable should occur with consequent rapid increase of the viscosity of the impregnant.

The impregnating oil which was used is known in the industry as *HC 3000*. Its constituents have a fairly narrow range of molecular weights, and the oil is much more nearly homogeneous with respect to molecular type than are natural petroleum oil impregnants. The oil is produced by polymerization of refined low-molecular-weight olefinic gases. Some of its properties are listed:

1. The viscosity at high temperature is about 30 times that of the higher-viscosity petroleum oil most widely used for cable impregnation. The low temperature characteristics are such that no difficulty results from installation at the minimum temperature (−10 degrees centigrade) considered normal in practice in the United States.

2. The oil is very stable electrically and its power factor is so low that it contributes only a negligible portion of the cable dielectric loss.

3. The oil is inherently of exceedingly low sulphur content, much lower than for natural petroleum oils, because of its production from low-molecular-weight olefinic gases which can be and are thoroughly freed from sulphur compounds.

The process of producing the *HC* oil raises a question of the possibility of a small content of organically bound chlorine. However, all of the oil used for the commercial production of the 1948 cable has a chlorine content of less than 0.01 per cent. Furthermore, extensive aging tests of paper impregnated with oil having four times this chlorine content have been made. In comparison with control tests on similar paper with various oils of low chlorine content, no difference is apparent in the aging characteristics.

Regarding the possible use of this oil in the more conventional mass-impregnation of cables, a careful investigation revealed that, with practical modifications of conventional methods, this would be entirely feasible. Essentially, this meant drying and impregnating at a temperature within the maximum range used for solid-type cable, but keeping the entire length at approximately this chosen temperature. In order to obtain the required uniformity of temperature for the mass-impregnation with the high-viscosity oil, electrical-conductor heating for drying became a requirement for long commercial lengths. With such heating, and with the use of pressure on the oil during the process, complete impregnation could be assured with no longer exposure of the paper to high temperature than in previous good practice.

In order to determine the effect of sudden temperature drops on the ionization starting potential of gas pressure cables impregnated with *HC-3000* oil by means of the mass-impregnation and the preimpregnation method, tests were conducted in which important temperature variations that occur in commercial cable operation were reproduced. In one series of tests, for instance, the cable load suddenly was reduced to zero, when the cable temperatures were stabilized, with the cable suspended in free air at 25 degrees centigrade and a conductor temperature of 100 degrees centigrade, and simultaneously a refrigerant at 0 degrees centigrade was circulated in cooling pipes provided on the outside of the cable. This test was applied several times to each cable sample. It was concluded from this study that the minimum ionization potential resulting during sudden temperature drops was safely above potentials that occur during normal service operation.

Performance tests for comparison of mass-impregnated and preimpregnated cables have been under way in Detroit in an experimental field installation since August 1947. Continuous load has been applied for a total of approximately 1,940 hours, with the conductor temperature at 100 degrees centigrade during most of the time. This was followed by 310 daily load cycles of 12-hour heating periods to 100-degree-centigrade conductor temperature and 12-hour cooling periods. A potential of 120 kv, three phase, was applied to the cable during all loading schedules. Power factor measurements made during the load tests have shown no significant change in the insulation.

Digest of paper **49-84,** "High-Pressure Gas-Filled Cable Impregnated With Extra-High-Viscosity Oil," recommended by the AIEE Insulated Conductor Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

Joseph Sticher and **G. H. Doan** are with the Detroit Edison Company, Detroit, Mich.; **R. W. Atkinson** and **Louis Meyerhoff** are with the General Cable Corporation, Bayonne, N. J.

Facsimile Transmission Speed

HENRY F. BURKHARD

OF GROWING importance to facsimile engineers is the problem of increasing the transmission speed. The speed may be increased by using special scanning methods, improving means for modulation and demodulation, using the available channel more efficiently, and using wider transmission channels.

Speed of transmission usually is limited by the usable band width of the available wire or radio transmission circuit and in some instances by the maximum recording speed of the recording medium. Since the scanning spot is just as likely to scan wide areas of constant shading as to scan isolated narrow lines, the frequency range of signals generated in the photocell circuit is from practically d-c to an infinite frequency. In a practical design, this range is considered to be from d-c to the fundamental frequency generated by the scanning of alternate black and white lines, each equal in width to the scanning aperture. When scanning an isolated spot equal in width to the scanning aperture, a continuous spectrum of frequency is generated. This spectrum may be found by means of a standard Fourier series analysis by assuming that the triangular wave which is generated is narrow and recurs at regular but widely separated intervals of time.

A second method for finding the frequency distribution is to treat the triangular pulse as an isolated pulse and insert its time function in the Fourier integral

$$f(w)=\frac{1}{2\pi}\int_{-\infty}^{\infty} f(t)e^{-jwt}dt$$

where $f(t)$ is found from the time plot of the pulse. For the triangular pulse, the result is

$$F(w)=\frac{1800E}{\pi}\left[\frac{1-\cos\dfrac{w}{1800}}{w^2}\right]$$

Both methods of analysis yield the same result.

Attempts are being made to utilize the available channel more efficiently. Delay distortion is usually the critical factor. The time of transmission of any single steady-state frequency through a medium is equal to the total phase shift in radians divided by 2π times the frequency. The inverse of this time usually is called the phase velocity. For practically distortionless transmission of modulation on a carrier, however, the criterion is that the envelope transmission time be constant over the frequency range being used. This envelope transmission time is equal to the slope of the phase-shift-versus-w curve. This latter curve, therefore, should be a straight line over the required frequency range. It was found that facsimile transmissions with a 1,000-cycle-per-second fundamental picture frequency were satisfactory when the envelope delay time at any and all frequencies in the required frequency spectrum was within ±250 microseconds of the mean envelope delay time of the required spectrum. In a special case when vestigial single-side-band modulation is employed, the ±250 microsecond need only hold over the frequencies ranging from the carrier frequency minus the vestigial frequency to the carrier frequency plus the vestigial frequency, provided the envelope delay time for all other frequencies in the required spectrum is held to within ±500 microseconds of the mean envelope delay time. To find the permissible envelope delay time for other than 1,000-cycle-per-second picture frequencies, divide the foregoing limits by the new picture frequency in kilocycles.

When the modulating frequencies exceed half the value of the carrier frequency, special precautions should be taken for modulation and demodulation. One method proposed by Radio Inventions, Inc., employs a carrier equal to about four times the maximum modulating frequency. The modulated signal is heterodyned down, and all but the lowest side-band signals are eliminated. Although the picture or modulating frequency is 2,400 cycles for newer low-speed equipment, these lowest side-band frequencies all fall within the contemplated Army voice channel. At the receiving machine, the signals are heterodyned back up prior to detecting and recording. The Radio Corporation of America, under Signal Corps contract, developed another method of detection in which the received signals are heterodyned with the sine and cosine waves of a higher frequency prior to detection.

The Times Facsimile Corporation normally accomplishes modulation within the phototube while utilizing a bridge circuit. They developed a balanced photocell arrangement to eliminate the modulating frequency components from the output of the bridge. This permitted higher ratios of modulating to carrier frequencies, since it no longer was necessary to separate the modulating frequency and the modulation products by filtering.

A study is in progress on the transmission of facsimile over wider channels up to 192 kc in width. Experimental equipment is being constructed to operate over 16-, 48-, 96-, and 192-kc channels. Since the practical limit of recording speed for the recording medium normally only would permit operation on the 48-kc channel, another means was investigated. Multiple scanning heads and recording helices to permit the scanning of one, two, or four scanning lines simultaneously were suggested. Since each line is scanned at a relatively slow rate of speed, the wet electrolytic medium was found to be satisfactory even at the 192-kc recording speed. At this higher rate of speed, it is anticipated that an 8-by-$10^1/_2$-inch facsimile image will be transmitted every seven seconds.

Digest of paper **49-108** "Considerations of Facsimile Transmission Speed," recommended by the AIEE Communication Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Transmission Line Charts

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The use of charts to reduce the labor in solving problems involving high-frequency transmission lines and wave guides has increased considerably. This article presents details of the development and problems illustrating applications of the two most commonly used types of charts. It was written primarily for students and practicing engineers who use the charts without knowing the background.

THIS ARTICLE contains no new information on the use of transmission line charts. However, for the benefit of persons not familiar with the charts and their applications, and for those who may have used the charts without knowing the theory involved, the development and some applications are presented with the mathematics simplified as much as possible.

When repeated calculations have to be made with complicated equations, a graphical solution often reduces the labor required. In the last decade much research has been done on transmission lines, wave guides, and antennas, and the same charts have been found useful for solving problems in all these fields.[1] Line charts are helpful in visualizing the manner in which the line input impedance varies with frequency, line length, or terminating impedance, and in determining the effects of mismatching, the points where matching stubs should be connected, points of maximum and minimum impedance, and so on. A variety of charts has been developed, depending upon the type of co-ordinates used, location of the origin, and choice of parameters. Only the two types most generally used, hereafter referred to as the rectangular chart and Smith chart, will be explained. The Smith chart[2,3] is the more popular of the two because it can handle calculations involving line attenuation more easily.

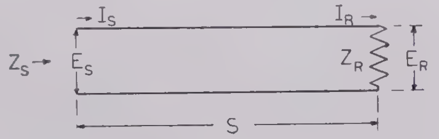

Figure 1. Definition of symbols

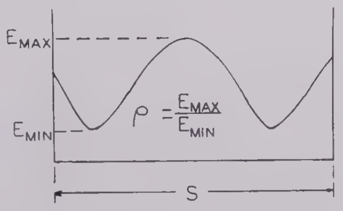

Figure 2. Definition of standing wave ratio

Definition of Symbols. Reference to Figures 1 and 2 will supplement the definitions to follow.

Z_R=line terminating impedance (receiving end)

Z_O=line characteristic impedance

$Z_S=\frac{E_S}{I_S}$=input impedance of a line of length S

S=distance measured from the load toward the input terminals

E_R,I_R=load voltage and current

E_S,I_S=voltage and current at a distance S from the load

E^+,I^+=incident-wave components of voltage and current, traveling toward the load

E^-,I^-=reflected-wave components of voltage and current, traveling toward the generator

(Note that $E_S=E_S^++E_S^-$, $I_S=I_S^++I_S^-$, and so on)

$\gamma=\alpha+j\beta$=complex propagation constant of the line

$\rho=\frac{E_{\max}}{E_{\min}}=\frac{I_{\max}}{I_{\min}}$=standing wave ratio (see Figure 2)

$K=|K|\,\epsilon^{j\phi}=\frac{Z_R-Z_O}{Z_R+Z_O}=\frac{E_R^-}{E_R^+}$=receiving-end reflection coefficient

$K_S=|K_S|\,\epsilon^{j\phi}=\frac{E_S^-}{E_S^+}=K\epsilon^{-2\gamma S}$=equivalent sending-end reflection coefficient looking toward the load

Other symbols will be defined later as they are introduced in the article.

RECTANGULAR CHART

The input impedance of a line of length S, terminated in an arbitrary impedance, Z_R, is given by

$$Z_S=Z_O\left[\frac{Z_R+Z_O \tanh \gamma S}{Z_O+Z_R \tanh \gamma S}\right] \qquad (1)$$

Now define the "normalized" input impedance as

$$z_1=r_1+jx_1=\frac{Z_S}{Z_O}=\frac{Z_R+Z_O \tanh \gamma S}{Z_O+Z_R \tanh \gamma S} \qquad (2)$$

The subsequent development will show that the locus of values of z_1 as S is varied is a circle (for a dissipationless line) if r_1 and x_1 are plotted on rectangular-co-ordinate axes. Thus the variations in z_1 as a function of S may be read directly from the graph once the circle has been plotted.

From the definitions of symbols previously given the following expressions may be obtained:[5]

$$E_S^+=E_R^+\epsilon^{\gamma S} \qquad (3)$$

$$E_S^-=E_R^-\epsilon^{-\gamma S} \qquad (4)$$

$$E_S=E_S^++E_S^-=E_R^+\epsilon^{\gamma S}+E_R^-\epsilon^{-\gamma S} \qquad (5)$$

But the receiving-end reflection coefficient is defined as

$$K=|K|\,\epsilon^{j\phi}=\frac{E_R^-}{E_R^+}=-\frac{I_R^-}{I_R^+} \qquad (6)$$

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Solving equation 6 for E_R^- and substituting in equation 5 gives

$$E_S = E_R^+\epsilon^{\gamma S} + KE_R^+\epsilon^{-\gamma S}$$

$$E_S = E_R^+\epsilon^{\gamma S}[1+K\epsilon^{-2\gamma S}] \qquad (7)$$

Now define a reflection coefficient, K_S, at a distance S from the load by expression 8. (Note that this is not equivalent to the sending-end reflection coefficient usually defined by the ratio $\frac{\mathcal{Z}_S-\mathcal{Z}_o}{\mathcal{Z}_S+\mathcal{Z}_o}$ in the literature.)

$$K_S = |K_S|\epsilon^{j\phi_S} \equiv \frac{E_S^-}{E_S^+} = \frac{E_R^-\epsilon^{-\gamma S}}{E_R^+\epsilon^{\gamma S}} = K\epsilon^{-2\gamma S} \qquad (8)$$

Substituting $\gamma = \alpha + j\beta$ in the above equation, and equating the magnitudes and angles of the resulting expression yields

$$|K_S| = |K|\epsilon^{-2\alpha S} \qquad (8a)$$

(Note that $|K_S| = |K|$ if $\alpha = 0$) and

$$\phi_S = \phi - 2\beta S \qquad (8b)$$

Using equation 8, equation 7 may be written

$$E_S = E_R^+\epsilon^{\gamma S}[1+K_S] \qquad (9)$$

and by a similar development

$$I_S = I_R^+\epsilon^{\gamma S}[1-K_S] = \frac{E_R^+\epsilon^{\gamma S}}{\mathcal{Z}_o}[1-K_S] \qquad (10)$$

Then using $\mathcal{Z}_S = \frac{E_S}{I_S}$ and dividing by $\mathcal{Z}_o$ to get the normalized input impedance

$$\frac{\mathcal{Z}_S}{\mathcal{Z}_o} = z_1 = r_1 + jx_1 = \frac{1+K_S}{1-K_S} \qquad (11)$$

Clearing fractions and solving for K_S,

$$K_S = |K_S|\epsilon^{j\phi_S} = \frac{r_1 - 1 + jx_1}{r_1 + 1 + jx_1} \qquad (12)$$

Now equate the squared magnitudes of the two sides of expression 12

$$|K_S|^2 = \frac{(r_1-1)^2 + x_1^2}{(r_1+1)^2 + x_1^2} \qquad (13)$$

By clearing fractions in equation 13, collecting terms, and dividing through by $(1-|K_S|^2)$, the expression

$$r_1^2 - 2r_1\left[\frac{1+|K_S|^2}{1-|K_S|^2}\right] + x_1^2 = -1 \qquad (14)$$

is obtained. Upon completing the square for the r_1-terms in equation 14 the equation becomes

$$\left[r_1 - \frac{1+|K_S|^2}{1-|K_S|^2}\right]^2 + x_1^2 = \left[\frac{2|K_S|}{1-|K_S|^2}\right]^2 \qquad (15)$$

This is the equation of a circle in the rectangular co-ordinates (r_1, x_1), with its center at

$$r_1 = \frac{1+|K_S|^2}{1-|K_S|^2},\ x_1 = 0, \text{ and radius} = \frac{2|K_S|}{1-|K_S|^2} \qquad (16)$$

As various values are assigned to $|K_S|$, a family of circles surrounding (but not concentric with) the point (1, 0) is obtained (see Figure 3).

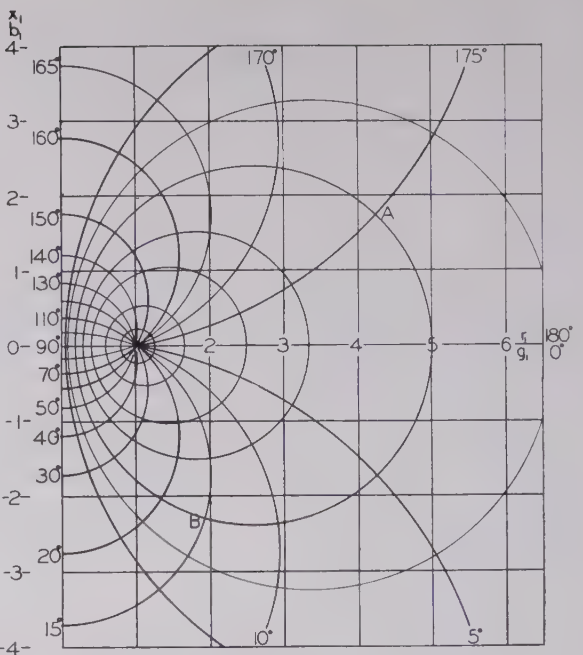


Figure 3. Rectangular form of line chart

For a dissipationless line, $|K_S| = |K|$ at any value of S, and the circle-representing a constant value of $|K|$ would be the locus of the values of the normalized input impedance $\frac{\mathcal{Z}_S}{\mathcal{Z}_o} = r_1 + jx_1$, as the distance S from the load is varied. On a line with dissipation the normalized load impedance, $\frac{\mathcal{Z}_R}{\mathcal{Z}_o}$, would be found on the circle determined by the value of $|K|$, whereas the input impedance, $\frac{\mathcal{Z}_S}{\mathcal{Z}_o}$, would be located on the corresponding $|K_S|$-circle determined from $|K_S| = |K|e^{-2\alpha S}$. This evidently would cause the locus of $\frac{\mathcal{Z}_S}{\mathcal{Z}_o}$ to move inward toward the point (1, 0) as S increases. The path would not be an ordinary spiral, however, because the successive $|K|$-circles are not concentric.

A chart containing only the constant $|K|$ circles would be incomplete because it would provide no means of determining how the impedance value moves along a given $|K|$-circle as a function of S, the distance from the load. Unfortunately, the arc-length traversed is not a linear function of S, so another set of curves for measuring this distance must be derived. The "line angle", βS, is a convenient unit for representation of distance on the chart because it can represent changes in frequency as well as changes in physical length. Referring to equations 8*b* and 12, ϕ_S is the angle which contains the desired parameter, βS. Thus, if the angles on the two sides of equation 12 are equated

$$\phi_S = \tan^{-1}\left(\frac{x_1}{r_1-1}\right) - \tan^{-1}\left(\frac{x_1}{r+1}\right) \qquad (17)$$

or

$$\phi_S + \tan^{-1}\left(\frac{x_1}{r_1+1}\right) = \tan^{-1}\left(\frac{x_1}{r_1-1}\right) \qquad (17a)$$

Equating the tangents of the angles represented by the equality 17a,

$$\tan\left[\phi_S+\tan^{-1}\left(\frac{x_1}{r_1+1}\right)\right]=\frac{x_1}{r_1-1} \tag{18}$$

and making use of the tangent of the sum of two angles equation 18 becomes

$$\frac{x_1}{r_1-1}=\frac{(r_1+1)\tan\phi_S+x_1}{r_1+1-x_1\tan\phi_S} \tag{19}$$

By cross-multiplication, collection of like terms, and completion of the square in the x_1-terms this becomes

$$r_1^2+\left[x_1-\frac{1}{\tan\phi_S}\right]^2=\frac{1}{\sin^2\phi_S} \tag{20}$$

This expression represents a circle in the rectangular coordinates (r_1, x_1) with radius $\left(\frac{1}{\sin\phi_S}\right)$ and its center at

$$r_1=0,\ x_1=\frac{1}{\tan\phi_S} \tag{21}$$

The circle represents the locus of all points having a constant value of ϕ_S. Choosing a series of values of ϕ_S results in a family of circles that pass through the point (1, 0) and that have their centers on the x_1-axis. (See Figure 3).

In using the chart the angle βS usually is required, rather than ϕ_S. The chart is entered at some point such as $\frac{Z_R}{Z_O}=r_1+jx_1$, and then a circle of constant $|K|$ (or a path corresponding to $|K|\epsilon^{-2\alpha S}$) is followed through an angle βS to locate the new point which defines $\frac{Z_S}{Z_O}$. Thus the chart is marked more conveniently in values of βS rather than ϕ_S. This may be done by assuming that K is real (obtained, for example, if $Z_O=R_O$ and $Z_R=R_R>R_O$), whereupon $\phi=0$ and $\phi_S=-2\beta S$. Then the circle obtained by substituting a given value of ϕ_S in equation 20 is designated on the chart by $\frac{-\phi_S}{2}=\beta S$. Thus the final form of the chart is obtained.

USE OF THE RECTANGULAR CHART

Input Impedance. Assume that the input impedance of a line of length S is to be determined when Z_O, α, β, and Z_R are known. The steps to be followed are

1. Calculate $\frac{Z_R}{Z_O}=r_1+jx_1$
2. Enter the chart at this point and move clockwise (the direction of increasing S) along a circle of constant $|K|$ through the angle βS.
3. If $\alpha=0$, read $r_1+jx_1=\frac{Z_S}{Z_O}$ at the point found in step 2.
4. If $\alpha>0$, calculate $|K_S|=|K|e^{-2\alpha S}$, and move along the final βS-circle found in step 2 from the $|K|$-circle to the $|K_S|$-circle. This locates the final point $\frac{Z_S}{Z_O}$. (The reader may recognize that the $|K|$-circles could be designated more conveniently in terms of the standing wave ratio, ρ, or the attenuation, αS, in nepers or decibels. This will be discussed in connection with the Smith chart).
5. Calculate $Z_S=Z_O(r_1+jx_1)$ at the point located in steps 3 or 4 to complete the problem.

Example. Suppose that $Z_R=423+j175$, $Z_O=100+j0$, $\alpha=0$, and $\beta S=20$ degrees. The value of Z_S is to be found. Following the steps gives

1. $\frac{Z_R}{Z_O}=4.23+j1.75$. Enter the chart at this point (point A in Figure 3). This is on the circle for $\beta S=175$ degrees.
2. Add 175 degrees+20 degrees=195 degrees. On the chart this is found as 15 degrees, and represents a 20-degree clockwise rotation from the original point.
3. Where the 15-degree circle intersects the $|K|$-circle containing the initial point, read $\frac{Z_S}{Z_O}=1.92-j2.30$ (point B in Figure 3).
4. Then $Z_S=Z_O\,(1.92-j2.30)=192-j230$ ohms.

Input Admittance. Let

$$Y_S=\frac{1}{Z_S},\ Y_O=\frac{1}{Z_O},\ \text{and}\ \frac{Y_S}{Y_O}=y_1\equiv g_1+jb_1 \tag{22}$$

Then by inverting equation 11

$$\frac{Y_S}{Y_O}=\frac{1-K_S}{1+K_S}=g_1+jb_1 \tag{23}$$

This expression results in the same families of circles as were obtained from equation 11. Thus Figure 3 becomes an admittance chart if r_1 is replaced by g_1, and x_1 by b_1. The procedure for admittance calculations is identical with that given for impedances. Calculations on an admittance basis are preferable if loads or matching stubs are connected across the line.

Conversion of Impedance to Admittance. This utilizes the relationship between the input and output impedances of a quarter-wave length dissipationless line. On such a line Z_o is purely resistive, $\alpha=0$, $\beta S=90$ degrees, and expression 1 may be simplified to yield

$$Z_SZ_R=Z_O^2 \tag{24}$$

Using equation 22 this may be written as

$$\frac{Z_S}{Z_O}=\frac{Z_O}{Z_R}=\frac{Y_R}{Y_O} \tag{25}$$

Thus the normalized impedance at some point on a line is equal to the normalized admittance a quarter wave length away. Therefore, the reciprocal of any normalized impedance value on the chart may be found by moving the point along the proper $|K|$-circle through an angular distance of 90 degrees.

Open-Circuited or Short-Circuited Dissipationless Lines. A short-circuited line has zero load impedance, and with no dissipation the input impedance is a pure reactance as S is varied. The locus of these points is the $|K|$-circle of infinite radius that corresponds to the x_1-axis of the chart. The input susceptance of an open-circuited line also has the imaginary axis as its locus.

Obviously, this chart cannot include impedance or admittance values equal to infinity, such as would be encountered on open- or short-circuited lines. The Smith chart does not have this limitation.

Other Uses. Many other calculations involving impedance-matching stubs, quarter-wave impedance transformers, and broad-band impedance-matching devices are simplified by using this chart. However, no further examples will be given because the Smith chart handles the same calculations with equal or greater facility.

SMITH CHART

The Smith chart shown in Figure 11 represents the same information as the chart of Figure 3. The straight-line loci of constant r_1 or x_1 in the rectangular chart become circles in the Smith chart as will be shown presently. The conversion of the first form of chart to the second may be made by means of a conformal transformation, but in this paper the Smith chart will be developed independently from the line relationships given in a foregoing section. The development for the rectangular chart may be followed through equations 9 and 10. Using equation 8, equations 9 and 10 may be written as

$$E_S = E_R{}^{+}\epsilon^{\alpha S}[\epsilon^{j\beta S} + |K_S|\epsilon^{j(\phi-\beta S)}] \tag{9a}$$

$$I_S = \frac{E_R{}^{+}\epsilon^{\alpha S}}{Z_o}[\epsilon^{j\beta S} - |K_S|\epsilon^{j(\phi=\beta S)}] \tag{10a}$$

Then

$$z_1 = \frac{Z_S}{Z_o} = \frac{\epsilon^{j\beta S} + |K_S|\epsilon^{j(\phi-\beta S)}}{\epsilon^{j\beta S} - |K_S|\epsilon^{j(\phi-\beta S)}} \tag{26}$$

Multiply numerator and denominator of this equation by $[\epsilon^{-j\beta S} - |K_S|\epsilon^{-j(\phi-\beta S)}]$ and combine coefficients of the $|K_S|$-terms to get

$$z_1 = r_1 + jx_1 = \frac{1 - |K_S|^2 + |K_S|[\epsilon^{j(\phi-2\beta S)} - \epsilon^{-j(\phi-2\beta S)}]}{1 + |K_S|^2 - |K_S|[\epsilon^{j(\phi-2\beta S)} + \epsilon^{-j(\phi-2\beta S)}]} \tag{27}$$

Using equation 8*b*,

$$z_1 = r_1 + jx_1 = \frac{1 - |K_S|^2 + j2|K_S|\sin\phi_S}{1 + |K_S|^2 - 2|K_S|\cos\phi_S} \tag{27a}$$

Equating the real and imaginary parts gives

$$r_1 = \frac{1 - |K_S|^2}{1 + |K_S|^2 - 2|K_S|\cos\phi_S} \tag{28}$$

$$x_1 = \frac{2|K_S|\sin\phi_S}{1 + |K_S|^2 - 2|K_S|\cos\phi_S} \tag{29}$$

These are the equations of circles in the polar co-ordinates $(|K_S|, \phi_S)$. Because equations 28 and 29 are not recognized easily as equations of circles, a transformation from polar co-ordinates $(|K_S|, \phi_S)$ to rectangular co-ordinates (u, v) will be made through the relationships obtainable from Figure 4.

From the figure:

$$u = |K_S|\cos\phi_S,\ v = |K_S|\sin\phi_S,\ \text{and}\ |K_S|^2 = u^2 + v^2 \tag{30}$$

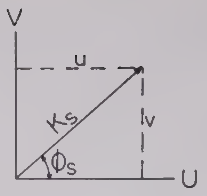
Applying the transformation equation 30 to equations 28 and 29 yields

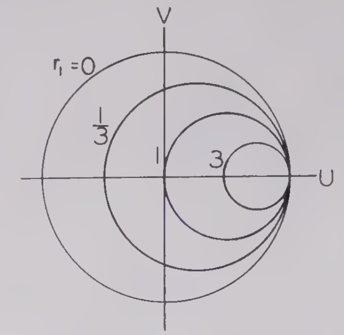
$$r_1 = \frac{1 - u^2 - v^2}{1 + u^2 + v^2 - 2u} \tag{31}$$

$$x_1 = \frac{2v}{1 + u^2 + v^2 - 2u} \tag{32}$$

Cross-multiplying equation 31, collecting terms, and completing the square in *u* results in

$$\left[u - \frac{r_1}{r_1+1}\right]^2 + v^2 = \left[\frac{1}{r_1+1}\right]^2 \tag{33}$$





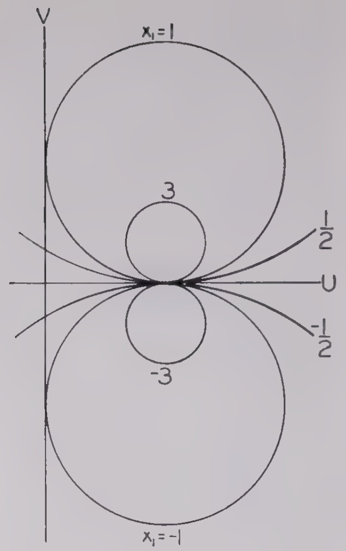


Figure 4 (top left). Transformation from polar to rectangular co-ordinates

Figure 5 (lower left). Circles having r_1 constant

Figure 6 (right). Circles having x_1 constant

If various values of r_1 are chosen, this equation defines a family of circles in the rectangular co-ordinates (u, v) with centers at

$$u = \frac{r_1}{r_1+1},\ v = 0;\ \text{and the radius} = \frac{1}{r_1+1} \tag{34}$$

All of these circles pass through the point (1, 0) as shown in Figure 5.

By a similar procedure, equation 32 may be converted to

$$[u-1]^2 + \left[v - \frac{1}{x_1}\right]^2 = \frac{1}{x_1{}^2} \tag{35}$$

This gives a family of circles for constant values of x_1, with centers at

$$u = 1,\ v = \frac{1}{x_1},\ \text{and radius} = \frac{1}{x_1} \tag{36}$$

All of these circles also pass through the point (1, 0), (see Figure 6).

In the development of the rectangular chart a circle of constant $|K|$ was shown to represent the locus of input-impedance values on a dissipationless line. On the polar-co-ordinate chart now under discussion, the loci of constant $|K|$ are circles concentric about the origin as may be seen from the relationships of equation 30. The expressions of equation 30 also indicate that the loci of constant angle ϕ_S are now radial lines from the origin, and that a given line angle βS represents a constant length of arc at any point on a given $|K|$-circle.

Figure 7 illustrates the constant-$|K|$ circles, and a typical scale of line angles. Since the value of ρ, the standing wave ratio, rather than the value of $|K|$ generally is known in experimental work with lines and wave guides, the $|K|$-circles usually are specified in terms of the corresponding value of ρ.

Their relationship is given by the following expression:

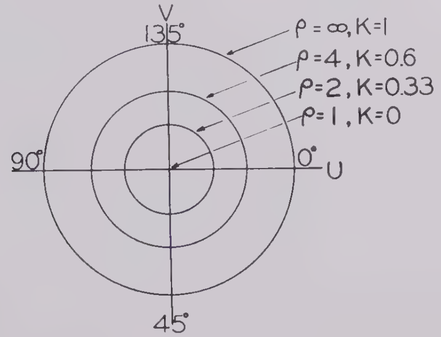
$$\rho=\frac{E_{\max}}{E_{\min}}=\frac{1+|K|}{1-|K|} \tag{37}$$

The value of ρ for a given circle is also equal to the r_1-coordinate (greater than 1) at which the ρ-circle crosses the u-axis of the chart. This is explained in the "applications" section. Corresponding values of ρ and K are indicated in Figure 7. An arbitrary angular scale calibrated in terms of $\beta S=-\frac{\phi_S}{2}$ with $\phi=0$, is shown also. Note that a complete revolution on a $|K|$-circle corresponds to a change of 180 degrees in the line angle because the standing-wave pattern and the input impedance values repeat at half-wave length intervals along a dissipationless line.

Now Figures 5, 6, and 7 may be combined to give the complete form of the Smith chart shown in Figure 8. The angular scale shown here ordinarily is replaced by a wave length scale (see Figure 11) whose zero point is chosen arbitrarily. A rotatable wave length scale would be desirable, since the measurement of line angle, βS, may begin at any desired value of $\frac{Z_R}{Z_0}$.

Lines with attenuation can be handled easily with this chart. The locus of input impedance becomes a logarithmic spiral described by $|K_S|\epsilon^{j\phi S}$, where $|K_S|=|K|e^{-2\alpha S}$, instead of the circle obtained for dissipationless lines. Since the value of ρ at the load, rather than $|K|$, generally will be known; a means of finding the standing wave ratio ρ_S at a distance S from the load would be useful. Referring to equation 37, an expression similar to this may be written for the point S.

Figure 7. Constant-K circles



$$\rho_S=\frac{1+|K_S|}{1-|K_S|} \tag{38}$$

Combining equations 37, 38, and 8*a* gives

$$\rho_S=\frac{\epsilon^{2\alpha S}+\left(\frac{\rho-1}{\rho+1}\right)}{\epsilon^{2\alpha S}-\left(\frac{\rho-1}{\rho+1}\right)} \tag{39}$$

for calculating the standing wave ratio at the input end of a line with dissipation when the attenuation constant and the load standing wave ratio are known. As an alternative, an attenuation scale may be provided for the chart by assuming that $\rho=1$ in equation 39, solving the expression to get

$$\alpha_S=\frac{1}{2}\ln\left[\frac{\rho_S+1}{\rho_S-1}\right] \tag{40}$$

and evaluating αS in nepers or decibels as shown in the table. Once such a scale has been determined, the difference in attenuation readings for the actual values of ρ and ρ_S gives the correct value for αS.

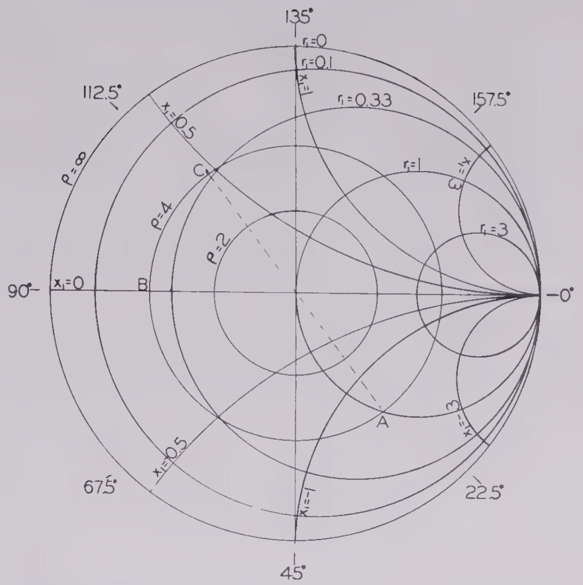


Figure 8. Abbreviated form of the Smith chart

ρ_S	αS in Nepers	αS in Decibels
∞	0.0000	0.000
20	0.0495	0.430
10	0.0995	0.864
5	0.203	1.77
2	0.550	4.78
1.5	0.805	6.99
1.1	1.522	13.22
1.05	1.857	16.13
1.02	2.305	20.02

Comparing Figures 3 and 8, a number of advantages of the polar form of the chart are immediately apparent:

1. The βS-scale is uniform in terms of the arc traversed on a given $|K|$ or ρ-circle, whereas this is not true of the rectangular chart.
2. All values of impedance (or admittance) from zero to infinity are found on the chart; that is, there are no $|K|$-circles of infinite radius.
3. The $|K|$-circles are concentric and equally spaced for equal increments in $|K|$. Thus a given amount of attenuation reduces the length of the radius vector ($|K|$) by a fixed amount at any polar angle.
4. Both the input impedance and input admittance of open-circuited lines may be found on the Smith chart. On the other hand the rectangular chart has the advantage that impedance or admittance values are represented directly by vectors drawn from the origin to the point in question, so that variations in magnitude and phase are visualized readily. This is not true of the Smith chart.

APPLICATIONS OF THE SMITH CHART

Input Impedance. The steps to be followed are identical with those outlined for the rectangular chart; therefore, they will not be repeated here. As an example, let point A in Figure 8 represent the normalized load impedance for a line, and suppose that $\frac{Z_S}{Z_O}$ is to be found at an angular distance $\beta S=63$ degrees from the load. Assume $\alpha=0$. Since point A is at 27 degrees on the βS-scale, adding 63 degrees + 27 degrees = 90 degrees locates Z_S at point B, where the $\rho=4$ circle intersects the real axis of the chart. Thus $\frac{Z_S}{Z_O}=0.25+j0$.

Input Admittance. By defining $y_1 \equiv g_1+jb_1$, and substituting g_1 for r_1 and b_1 for x_1, the chart becomes an admittance chart. (On the standard Smith chart read "conductance" for "resistance," and "susceptance" for "reactance.") The input admittance at a given distance from a known load admittance may be found in exactly the same way as the impedance calculation in the foregoing.

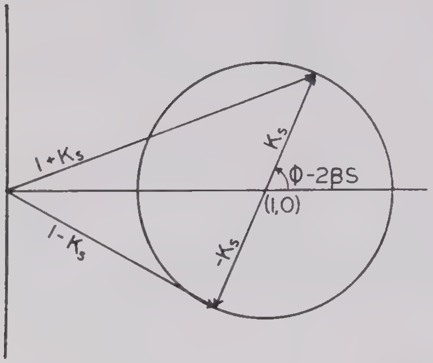


Figure 9. Illustration of the components of equation 44

Conversion of Impedance to Admittance. The principles already have been outlined in connection with the rectangular chart. The operation is much simpler on the Smith chart, however, because a 90 degree rotation (in βS) from an impedance to its corresponding admittance is represented by an actual angle of 180 degrees, thus placing the two points at opposite ends of a diameter of the corresponding ρ-circle. For example, point C in Figure 8 represents the admittance equivalent to the impedance of point A. If $\frac{Z_R}{Z_O}$ is found at A, the co-ordinates of C represent $\frac{Y_R}{Y_O}$.

Standing Wave Maxima and Minima on Dissipationless Lines. The standing wave ratio ρ and the position of a voltage maximum or minimum are the quantities most easily measured on high-frequency lines and in wave guides. The location of the voltage maxima and minima on the Smith chart now will be investigated for dissipationless lines, since this information is essential to the determination of unknown load impedances in terms of the measurable quantities mentioned in the foregoing.

On a line with no dissipation, $Z_O=R_O$ and $\alpha=0$. Referring to equation 11, and substituting the definitions of K_S and K, the normalized input impedance to the line may be expressed as

$$\frac{Z_S}{R_O}=\frac{1+K_S}{1-K_S}=\frac{1+|K|\epsilon^{j(\phi-2\beta S)}}{1-|K|\epsilon^{j(\phi-2\beta S)}} \qquad (41)$$

The components of this expression are shown in Figure 9. Reference to equations 9 and 10 will show that the magnitude of the line voltage versus distance is determined by $|1+K_S|$, and that the line current magnitude is proportional to $|1-K_S|$. From Figure 9 and equation 41 the line input impedance is evidently a maximum or minimum where the angle $(\phi-2\beta S)$ is 0 degrees or 180 degrees, respectively.

Thus

$$\frac{Z_{S\max}}{R_O}=\rho, \text{ and } \frac{Z_{S\min}}{R_O}=\frac{1}{\rho} \qquad (42)$$

These points also correspond to the voltage maximum and minimum, and on the Smith chart they are found where the ρ-circle crosses the axis of $x_1=0$.

Determination of Unknown Load Impedance. Assuming that the standing wave ratio and the distance from the load to some convenient voltage minimum can be determined, the value of an unknown load impedance may be found easily with the Smith chart.

Example. Let point B in Figure 8 represent the normalized input impedance at a voltage minimum on a dissipationless line with $\rho=4$. Assuming that the voltage minimum is 63 degrees from the load, the normalized load impedance is found by moving counterclockwise along the $\rho=4$ circle to point A.

Addition of Impedance in Series or Parallel at Some Point on the Line. If a series resistance is added to an impedance $\frac{Z}{Z_O}$, or a shunt conductance is added to an admittance $\frac{Y}{Y_O}$, the impedance or admittance locus on the chart moves along a line of constant x_1 or b_1 in the direction of increasing r_1 or g_1. Similarly, if a series reactance or shunt susceptance is added at some point, the impedance or admittance locus moves along a line of constant r_1 or g_1 in the direction of increasing x_1 or b_1, taking the algebraic sign of the added quantity into account.

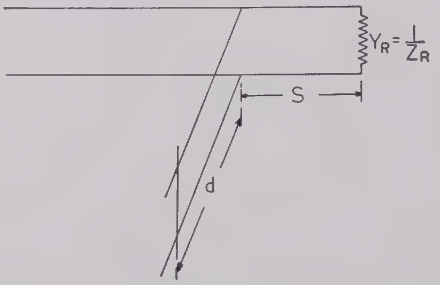


Figure 10. Use of a single impedance - matching stub on a parallel-wire line

The added quantities must be normalized; that is, divided by Z_O or Y_O, before the foregoing operations are performed. An example will be given in the next section where a parallel stub line is used for impedance matching.

Impedance Matching with a Single Parallel Stub Line. Figure 10 illustrates the use of a parallel stub line to provide an impedance match between a transmission line and its load.

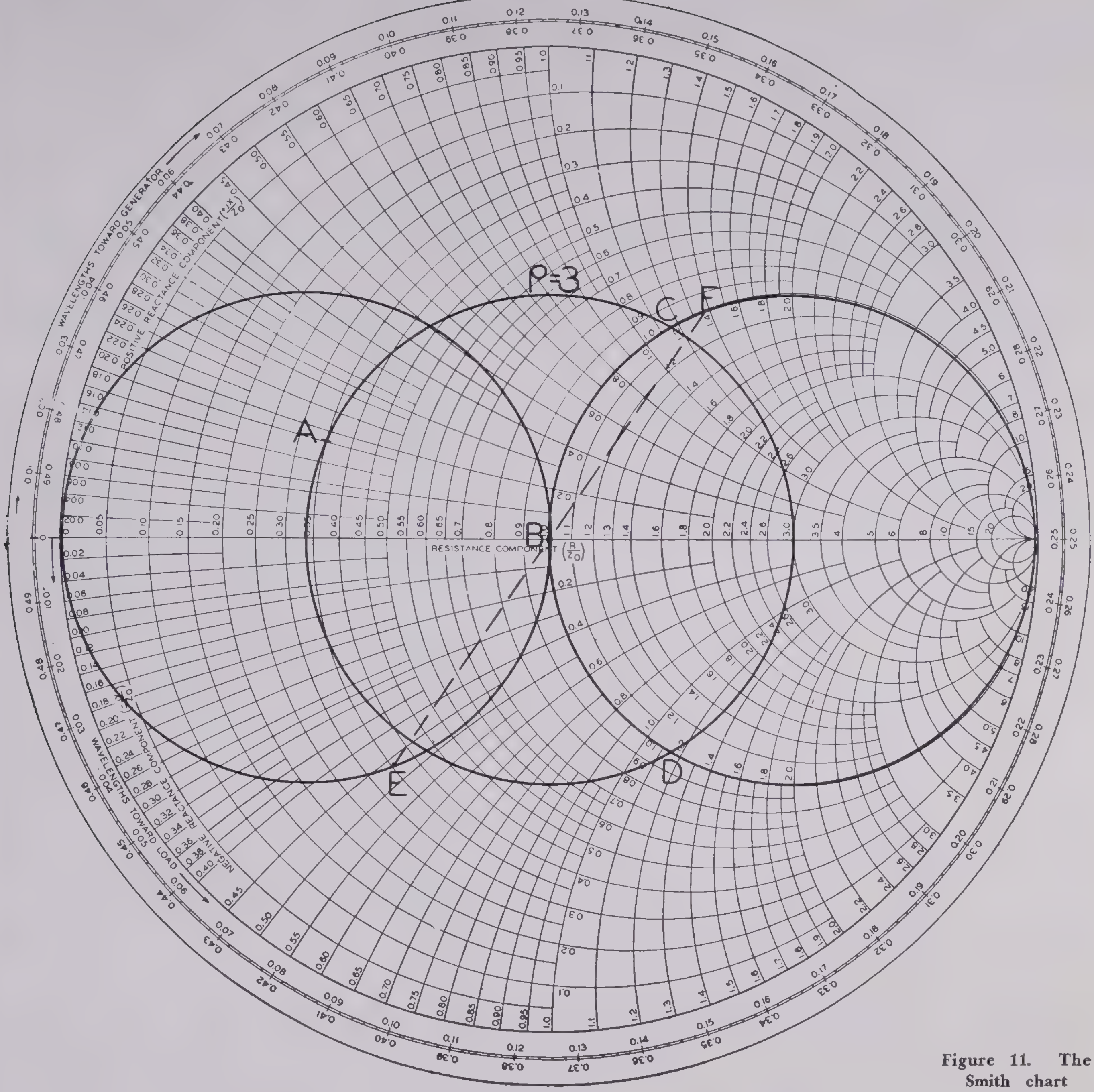


Figure 11. The Smith chart

The distance S from the load to the point of stub connection is chosen so that the input admittance to this length of line terminated in the load Z_R has a conductance component equal to the G_0 ("characteristic conductance") of the line. If the line is dissipationless, $G_0 = 1/R_0$. At this point an open-circuited or short-circuited dissipationless stub line is connected in parallel, thus providing a parallel susceptance of such a value that the total susceptance at the point will equal the characteristic susceptance of the line. On a dissipationless line, $B_0 = 0$, therefore the susceptance should be equal and opposite to the input susceptance of the length of line S terminated in Z_R. In either case the line from the generator then will be terminated in its characteristic admittance at the point of stub connection. Standing waves will exist on the stub and on the line between the stub and the load, but not on the line between the generator and the stub. The benefits derived from obtaining an impedance match at the load are that the transmission efficiency of the main line will be increased[5] and that maximum power transfer between the line and load will be obtained.

The matching stub should be placed as close to the load as possible to eliminate standing waves over the major portion of the line from the generator. A short-circuited stub generally is used because the stub length is easier to adjust than that of an open-circuited stub.

The calculation for single-stub matching is illustrated in Figure 11, in which the lines necessary to demonstrate single-stub and double-stub matching have been added to the Smith chart. A lossless line and stub are assumed. In

Figure 11, let point A represent the normalized load admittance. This must be transformed to B (center of chart) in order to match the line impedance. Varying the distance S in Figure 10 corresponds to moving around the $\rho=3$ circle in a clockwise direction to either point C or D where $g_1=1$. If C is chosen as the point of stub connection, the arc AC represents the length S. Now a negative susceptance (due to the stub) added at C will move the point around the $g_1=1$ circle to B.

The procedure for determining the length of the stub and the distance S to the point of connection is as follows:

1. Locate the point Y_R/Y_O either from the known value of Y_R, or by the method given under "Determination of Unknown Load Impedance," using admittances instead of impedances.

2. From this point move around the ρ circle to the first point where the input admittance, $y_1=g_1+jb_1$, has $g_1=1$ which gives an input conductance equal to the G_O of the line. This will occur where the given ρ circle intersects the circle for $R/Z_O=1$, and locates the point of stub connection.

3. Find the length of open-circuited or short-circuited stub required to produce a susceptance equal and opposite to that found at the point where $g_1=1$. This value is located on the circle for $\rho=\infty$ (assuming the stub is dissipationless).

Example. (Use the chart of Figure 11.) A line has $\alpha=0$, $Z_O=100+j0$, $Z_R=65+j115$,

Then $\dfrac{Z_R}{Z_O}=0.65+j1.15$. Locate this on the chart, on the $\rho=4$ circle.

1. Draw a diameter of the circle to get $\dfrac{Y_R}{Y_O}=0.37-j0.65$.

2. Go around the circle (toward generator) to $\dfrac{Y_S}{Y_O}=1.0+j1.5$. The distance traversed is 0.276λ, determining the point of stub connection.

3. A short-circuited stub has $\dfrac{Y_R}{Y_O}=\infty$, which is found at the right end of the real axis $\left(\dfrac{R}{Z_O}=\infty \text{ on the chart}\right)$. Moving clockwise around the outer circle to the point where the susceptance is $-j1.5$ gives a required stub length of 0.093λ.

Double-Stub Impedance Matching. In using coaxial lines, the matching stub no longer can be connected at will to any arbitrary point on the line because of the necessity of drilling a hole in the outer conductor. Once this has been done, the stub position cannot be changed when a new load impedance is substituted. One way of overcoming this difficulty is to insert a variable-length section of line between the stub and the load. However, because of the consequent need for flexible lines and the difficulty of making a variable-length section with constant impedance throughout its length, this method is actually not very good for microwave work.

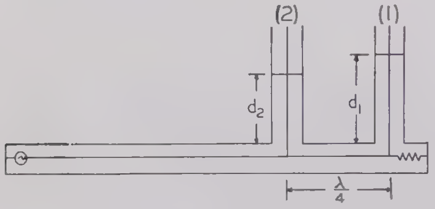


Figure 12. Use of two matching stubs on a coaxial line

A better solution is to use two or three tuning stubs with a fixed spacing. The case of two independently tuned stubs spaced one-quarter wave length will be considered here. One of the stubs is assumed to be at the load, although this is not a necessary condition. Figure 12 shows the arrangement of the stubs on the coaxial line. Stub *1* may be used to add positive or negative susceptance in parallel with the load.

The resulting admittance is transformed to the opposite side of the chart by the $\frac{\lambda}{4}$ line; and if an impedance-match is to be obtained, this point must lie on the $g_1=1$ circle. Then the susceptance of stub *2* is added (as in the case of single-stub matching) to transform the admittance to the center of the chart.

The manipulations involved in double-stub matching are illustrated in Figure 11. Assume the load admittance at A is to be matched to the line admittance at B. The short-circuited stub *1* adds negative susceptance to the admittance at A, moving the point along a line of constant g_1. The proper amount of susceptance must be added by stub *1* so that the resulting admittance may be transformed by the $\lambda/4$ line to a point on the $g_1=1$ circle. Since the $\lambda/4$ line transforms admittances to opposite ends of the diameter of a circle of constant ρ, the locus of admittances that can be transformed to the $g_1=1$ circle by such a line easily is seen to be a similar circle on the left side of the chart. Therefore stub *1* should be of the proper length to transform the admittance from A to E in Figure 11. The $\lambda/4$ line then transforms E to F; and stub *2* then is adjusted to have the proper susceptance to move the admittance from F along the $g_1=1$ circle to B.

Further consideration of Figure 11 and the process involved in double-stub matching will show that for the conditions chosen here (stub *1* at the load and $\lambda/4$ spacing between stubs) only those load admittances with $0 \leq g_1 \leq 1$ can be matched to the line. Therefore, other stub positions and spacings, or the use of three stubs may be preferable in some applications.

CONCLUSION

In conclusion it would be well to repeat that, although the examples of use of the charts discussed in this article have been referred to transmission lines, most of them are equally applicable to wave guides. The matching stubs and other impedances that may be connected into a wave-guide system may have an entirely different physical form from lines, but the calculations of impedance and admittance are performed in the same way, the necessary physical measurements being made in terms of the standing waves of electric or magnetic field intensity in the wave guide.

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Characteristics of 2-Phase Servomotors

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MEMBER AIEE

IN THE past few years, small 2-phase induction motors have become quite popular for use as servomotors in control systems where relatively small torques are required.

Fundamentally, these motors are similar to the 2-phase squirrel-cage induction motor. However, there are important differences in operating conditions and in design values. Two-phase servomotors are operated practically always on unbalanced terminal voltage for, to achieve control of torque, speed, and sense of rotation, the control-winding voltage may be varied from rated value in one sense through zero to rated value in the opposite sense, while the voltage on the other winding, called the main winding, is held constant.

With respect to design values, the air gap is relatively large, and in order to secure stable control, the speed-versus-torque curve must cross the zero speed axis with negative slope. These conditions mean relatively high exciting susceptance and rotor resistance.

An analysis of the performance of 2-phase induction motors as servomotors yields the following:

$$V_{M1} = \frac{V_M}{2}(1+k) \tag{1}$$

$$V_{M2} = \frac{V_M}{2}(1-k) \tag{2}$$

where

V_M = voltage applied to main winding
V_{M1} = the positive-sequence component of main-winding voltage
V_{M2} = the negative-sequence component of main-winding voltage
k = ratio main-winding voltage to control-winding voltage

Positive- and negative-sequence torques are respectively

$$T_1 = \left(\frac{V_{M1}}{V_M}\right)^2 T_{B1} \tag{3}$$

$$T_2 = \left(\frac{V_{M2}}{V_M}\right) T_{B2} \tag{4}$$

$$T = T_1 - T_2 \tag{5}$$

where

T_{B1} is the torque due to balanced voltage, V_M, at slip S

T_{B2} is the torque for slip 2-S

T is the net torque

A family of calculated speed-torque curves for a servomotor having typical constants is shown in Figure 1. Curve F corresponds to operation on balanced voltage and is calculated by methods quite generally used. The other curves can be obtained easily by calculating the component voltages from equations 1 and 2, reading T_{B1} and T_{B2} from curve F, and substituting into equations 3, 4, and 5.

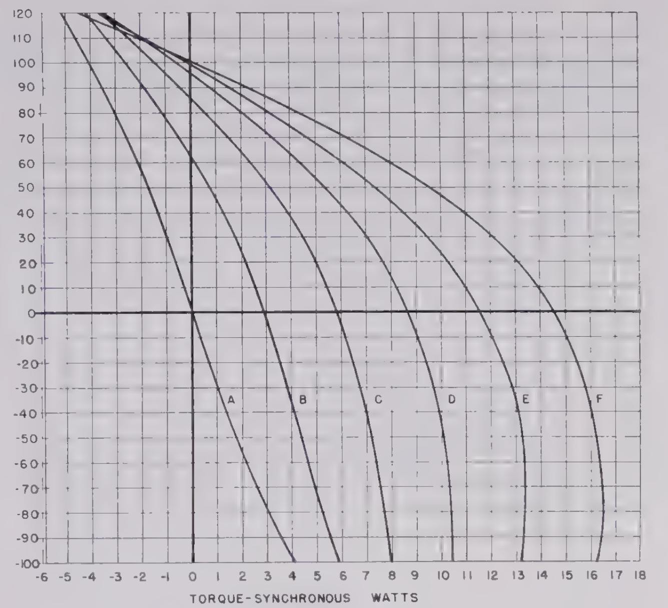

Figure 1. Per cent synchronous speed versus torque in synchronous watts for servomotor operating with external impedance in control-winding circuit equal to zero

Curve A is for control voltage corresponding to $k=0$; B, $k=0.2$; C, $k=0.4$; D, $k=0.6$; E, $k=0.8$; F, $k=1.0$

When the control winding is supplied through a resistance, the formulas for the components of voltage become considerably more complicated. However, if the control voltage is increased to compensate for the external impedance drop, the shapes of the curves over the normal operating range are quite similar.

In the design and analysis of control systems, it is important to know the relation between servomotor control voltage and torque. Information contained in Figure 1 may be replotted to show that this relationship is very nearly linear over normal operating speed ranges. It can be shown to be exactly linear at zero speed from theory.

Another important factor in control system design is the internal motor damping factor which is the negative reciprocal of the slopes of the curves of Figure 1. These factors vary widely with voltage and speed.

If the control-winding voltage is made zero it can be seen from equations 1 and 2 that the positive- and negative-sequence voltages will be equal. If the motor has a speed-torque curve typical of high rotor resistance crossing the zero speed axis with negative slope as shown by T_{B1} and its continuation, T_{B2}, in Figure 1, it can be seen that the negative-sequence torque will be larger than the positive, and thus prevent rotation regardless of the rotor speed.

Digest of paper **49-81**, "Operating Characteristics of 2-Phase Servomotors," recommended by the AIEE Rotating Machinery Committee and the AIEE Joint Subcommittee on Servomechanisms, and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31-February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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The Flux Field in the Shaded-Pole Motor

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THE SHADED-POLE induction motor traditionally has been built but not designed. In the present state of the art, it is more practical to build a series of trial motors with modifications to produce the desired characteristics than to design one meticulously and still miss those characteristics. This article is intended to show some of the causes of failure of the usual design procedures. The results are qualitative only, but it is hoped that they will aid designers quantitatively through the use of presently known design constants which have been obtained from experience with their own motors.

To determine the flux distribution around the air gap at any chosen instant of time, the magnitude of flux shown by the time trace on the oscilloscope screen at that instant, as seen on the repetitive synchronized traces, was recorded and plotted against space degrees around the air gap, as the measuring circuit was switched to successive air gap exploring coils around the pole face. The same was repeated for instants of time successively later by 30 degrees. When the shading-coil circuit was open, the space waves plotted for 30-degree time intervals showed standing waves of both fundamental and third harmonic flux.

If the fundamental field traveled around the air gap at synchronous speed, the double revolving field theory could account for its nonconstant magnitude. However, observations and analyses show that the field varies from point to point in time around the air gap, not only in magnitude but in speed as well. In the special motor built in large size and tested, the fundamental field traveled at more than $2^1/_2$ times synchronous speed around some portions of the air gap and, of course, at much less than synchronous speed around other portions. In this article, the position of the fundamental field is plotted against time to show its abberation from the ideal. Figure 1 shows a plot of apparent velocity and magnitude of the fundamental field as it travels once around the air gap. This plot is not completely satisfying because of the few calculated points available for plotting. This erratic magnitude and velocity leads to difficulties in attempting to apply the usual rotating field theory.

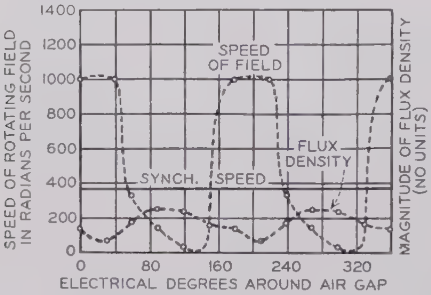

Figure 1. Speed and flux density of fundamental field with rotor blocked

Shading coil resistance slightly higher than normal

An analysis of the third-harmonic field (no higher investigated) shows some conditions under which the field is a standing wave and others in which it is moving forward or backward. With the shading coil resistance adjusted for maximum torque, the third harmonic field moves forward at one-third synchronous speed and contributes to the starting torque. When the shading coil resistance is too low, the third harmonic field moves backward and detracts from the starting torque.

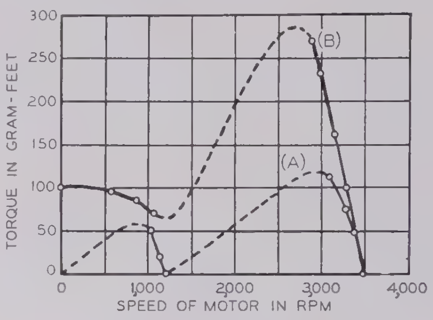

Figure 2. Speed-torque characteristics of motor

A—With shading coils open
B—With shading coil resistance same as in Figure 1

It is believed that the function of the magnetic bridge between adjacent poles has been clarified. Its purpose is to improve the permeance of the path taken by the flux, which is mutual to the exciting coil and the shading coil. It also serves to divert this mutual flux from a path through the rotor where it is a detriment to the starting torque because of the small time angle by which it lags the flux through the unshaded portion of the pole.

The effect of too little resistance in the shading coils is shown by loss of starting torque. The flux produced by the shading coil ampere-turns is shown to be confined to a local path which crosses the air gap twice. Those fluxes then do not "join hands" from coil to coil around the air gap. No attempt has been made to correlate the shading coil current and resistance as they are related to heating of the coil or efficiency of the motor. Figure 2 shows the speed-torque characteristics of the experimental motor with and without shading coils.

Digest of paper **49-72**, "The Field Fluxes of the Shaded-Pole Motor," recommended by the AIEE Rotating Machinery Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Industrial Exploration and Development

J. F. DOWNIE SMITH

Research, today, is a complicated process, entailing the services of an entire series of specialists. Assuming that a given company can justify the cost of a research department, the author goes on to examine some of the shortcomings and possibilities of industrial research and development work.

IT IS REALIZED that there is a widespread misunderstanding, or shall we say misuse, of the word "research" and so this article has been entitled "Industrial Exploration and Development," rather than "Industrial Research and Development," which is more common in the mechanical engineering field. What is research to one man is distinctly development to another, and at times it is difficult to lay down rules regarding a proper line of demarcation. This article deals with the operation of a division of a company which ordinarily might be named Research and Development in mechanical engineering, and will cover the product and the personnel.

While the author's experience has been largely in the mechanical engineering field, the procedures involved are about the same for most of the other industrial engineering companies, although in some electrical companies the division might be listed almost entirely in the development field.

SHOULD THERE BE A RESEARCH DEPARTMENT?

Can the company justify a research organization? In general, research these days involves the use of more experience than one man ordinarily could be expected to have. Thus, in each research organization of any size a whole series of specialists has been developed, each man to handle all of the problems in his field in the entire organization. For example, in one organization there is a specialist in gears and mechanisms, another in hydraulics, a third in electric control equipment, a fourth in motion-time analysis, a fifth in metallurgical engineering, a sixth in cam mechanisms, a seventh in testing techniques. Because of the ramifications in the development of a fairly complicated machine, it is seldom desirable for a company to set up a research organization unless it is prepared to spend more than $100,000 a year for research and development. Where the company is small or such an outlay is undesirable, it is generally better for that company to have its research done elsewhere, at one of the industrial foundations such as Battelle Memorial Institute or Armour Research Foundation, or at a technical college such as Iowa State College where it can be handled as a project. At a research institute or at a technical college, there is generally available on the staff a collection of talent which would not be available in a small research organization in industry. However, several defects in the handling of work in that way are obvious to one who has come from an industrial organization. In industry a close check is kept on all projects to ascertain that the research worker does not stray from the primary objective along an alley that looks promising to him at that time, while in colleges there is sometimes such a tendency, and thus proper direction of the work has to be assured.

Assuming that the cost can be warranted, what would be some of the pitfalls of such a department? The ones I shall discuss are connected with the mechanical industries, but would apply to electrical engineers also.

BUSINESS VIEWPOINTS

As the principal object of research in most industrial concerns is the development of some new product or process, a constant check has to be kept, not only on the technical aspects, but also on the business aspects. For example, if a process can be developed by research which indicates that a certain thing can be done, but a business analysis shows that even if it were done it would not be feasible, there is little point in continuing the research much further. This type of control is responsible for a large part of the dissatisfaction of research workers. When a research man is in the middle of a problem and believes that he has made rapid progress, he hates to be stopped from further work, and so feels that any businessman who stops him for business reasons does so because he does not have a scientific appreciation of the problem. Very often this is true and the decision to stop certain problems and continue with others is the wrong one. On the other hand, the businessman makes such decisions on the basis of what the engineers and scientists have convinced him are the possibilities. If the research man is incapable of presenting a clear picture of the possibilities, it is not at all surprising that the businessman frequently turns him down. We all know of instances where a second-rate idea has been pushed through successfully, whereas a first-rate idea has been largely neglected, because of the superior selling power of the man on the first job.

A research department must demonstrate to the company that in the long run it is worth its cost. Frequently the management of a research organization is too impatient to wait for results from research, and these almost invariably take longer than the layman would expect, but no company can justify a layout for research year after year if no returns from that research are coming in or are expected within a reasonable time. If such a research organization does

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Full text of an address, "Industrial Research and Development," presented at the AIEE Great Lakes District Meeting, Des Moines, Iowa, April 1–3, 1948.

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exist, it is clear that the research management is in danger of being displaced by more competent research management. This means that the skillful research administrator or executive should try at an early stage to show where his research is benefiting the company. In the process of doing so, however, he should not make the mistake of assuming that all the progress made by the company is made by the research department. For example, in the working out of a new product, the research division should consult with the various other departments which will be concerned with the finished product before production begins—the sales staff, tool and production engineers, shop foremen, and so forth. Where those people have contributed to the finished product, credit should be given to them. This helps to smooth the way in the developing of new products. Indeed, from the standpoint of the research administrator, it very often pays to give the production men more credit than they really deserve. In many instances a research organization has to do a selling job as well as research, and a little bit of overpraise of others who have contributed might be worth a great deal in the developing of a research division.

The development of a new product is not something which can be analyzed entirely from the business standpoint. For example, several years ago one of the big aluminum companies in the country was approached to see if it would make an aluminum tank car to handle the special products of one small manufacturer. The aluminum company had its business research man analyze the potential field for tank cars to handle that particular product and, finding that only one or two such cars would be necessary for the whole country, refused the assignment. The small manufacturer then went to a job shop and asked them if they could make such a car, and if they would be willing to do so. Their chief engineer replied, "Why, certainly we can make it," and without giving it any business analysis, he made one. The car traveled the railroads and interested many people as a solution to some of their own problems, and before long a sizable order was placed for such aluminum tank cars. This is not a plea for less business control of research, but an indication that business control has to be guided properly for it to be completely satisfactory.

After a product has been developed, it has to be sold or leased, and so the company might be expected to go into large-scale production immediately. It may be argued that this is what is done in the mass production industries. Actually, however, it is not. A glance at the progress in the automobile industry since its beginning will show that no great change has been initiated in any one year by any major company without serious danger that the public would not accept the product. The development of the Chrysler Airflow, which was actually a very distinct engineering achievement, was too advanced for the average buyer at that time, but the engineering advances in that car since have been adopted by almost every automobile manufacturer in the United States. Thus if a radical improvement in a product is to be expected, it might be better to put out such a device in engineering in the same way that a pilot plant is developed in the chemical engineering industries before a full-scale production plant is built. In the machine tool industry, for instance, this might mean manufacturing a limited quantity of such items for local sale before inaugurating large-scale production. Frequently the cost of the final product would be more than if full-scale production had been started immediately, but this might be good insurance.

THE BUSINESS MANAGEMENT OF ENGINEERING

Business management has a constant finger in the research pie. The cost of each phase of the business is, in general, of little interest to the research man, and someone has to keep him cost-conscious. Frequently, in order to give the businessman, general manager, and the chief engineer or technical director a proper indication of progress, reports are requested from each section head on each of the developments under his control. The time between those reports should not be more than one month, but one week is too short a period. If a section head is asked to prepare a progress report every month on a job where expenses keep rising, after a time, if progress cannot be shown, he will take a more active interest in that particular item and see that progress is made. If progress is delayed in a development department because certain matters are unknown, the problem should be taken from the development department and reassigned to a research department where more latitude can be given in cost matters.

In general, the management of an engineering department is handled by a technical man who probably knows engineering quite well, but whose business training is likely to be slight. For that reason, he often cannot handle *both* engineering and business matters to best advantage. In one company with which the author was associated, the business aspects of engineering assignments were handled by business-trained men reporting to the director of research, thus relieving the engineers, including the chief engineer, of all business responsibilities. For example, if a contract with an outside concern was to be set up for a development project, the chief engineer would be called in to consider the engineering aspects of the program, or if someone else in the organization was better prepared to handle the technical matters, he would be consulted. But the handling of the contract, and the proper following up of this contract with the outside concern, would be done by the business representative. Because this businessman was responsible to the director of research, and not to the chief engineer, there was at times a feeling that the general management was not given the engineering picture as fully as the engineers would like. Nevertheless, on the whole, this system worked very satisfactorily and often was envied by project or chief engineers in other concerns who had to handle all phases dealing with individual contracts.

Research in production items requires a constant watch over costs. For example, in one instance the author believed that an improvement could be made in the sound deadening on automobile doors which would eliminate the filthy section in the plant devoted to the spraying of the tarry material. One of the wide automobile doors was taken off the production line and the proposed change was made. It worked beautifully. Then a cost estimate was made, and it was found that the new scheme would cost 1.12 cents per pair of doors, or per car, more than the original. As a first attempt, it looked encouraging to the author—but the automobile company was not sufficiently interested even to look at it when they saw the price differential.

Research on production items frequently has its humorous side, also. When one of the railroad companies operating out of Chicago wanted to get a sound analysis of one of its trains in an endeavor to cut down on the sound level, the author was assigned the job with some assistants. For comparison purposes a sound analysis also had to be made of a competitive train, and this, of course, posed some problems, for it would have been awkward explaining the reasons for the test. However, everything went smoothly until the last car was reached, and there the conductor was met. He asked the author and his assistant what was going on, and, unabashed the assistant said: "I am taking some graduate work in college, and this is my professor." Considering the fact that he was about 55 years old, and the author about 35, there was some feeling of relief when the conductor believed the story.

Among the results of this research was one item of considerable interest. Inside the car the principal noise was found to come from the vibration of the wheel when it hit something. The frequency of vibration was quite high, and almost continuous, regardless of speed. However, it was discovered that the cure could be effected very simply, so that when the wheel was struck by a hammer it was like hitting a block of wood, whereas the untreated wheel rang like a bell. The general management was very much impressed and insisted that every car from then on must be equipped with that device. Some two years later, the author checked back to find out if many such wheels had been turned out, and discovered that not a single one had been. The railroad men of general management level approved the idea whole heartedly, but the mechanics decided that it would spoil their practice of hitting a wheel with a hammer to detect cracks. They couldn't hear anything. This was one good idea gone wrong.

RESEARCH COSTS

Many large research organizations try to charge the cost of all research and development men to particular jobs or projects. Where there are several specialists, and each man works on perhaps a dozen different projects in a week, it soon becomes a tiresome chore for a research man to break down his time satisfactorily, and the making out of time cards for research workers ordinarily is looked upon as beneath their dignity. Where it is possible at all, it is better to put the research worker on overhead and have the time spent by the various research workers apportioned by the section or department head. This may seem antagonistic to good business practice, but it is remarkable how much animosity can be built up in the minds of research workers by such minor routine and red tape.

GENERAL PERSONNEL RELATIONS

Programs for Advancement. The management of a research organization should have definite plans for advancement of every capable employee, and these plans should be made known, in so far as possible, to the person concerned. It is important that the latter be advised of his shortcomings, as well as of his desirable characteristics, and he should be told what is to be expected in preparation for the next step in the plan. Everyone in the organization should have at least one management representative, not necessarily his immediate superior, who is actively interested in increasing the employee's value to himself and to the company. In research organizations there frequently is not a personnel manager, and there should be if the company is large.

Explaining Company Policy. Too frequently company policy does not go further than the general management and the research worker does not know why he is doing what he is, and why the company is doing what it is. In general, a management policy affecting the workers should be explained to them.

Worker Faults. It does not pay to have a third-rate worker continue to consider himself first-rate merely because he is not told of his deficiencies. It is better to tell such men, so that they have a chance to improve, and to realize what they lack. Otherwise, they think that they are being deliberately held back because of favoritism. If the man still continues to feel as he does after a suitable cooling-off period, an effort should be made to place him in some other department.

Training Programs. There should be a constant training program for younger men to take over the senior executive positions at the proper time. Frequently this is critically neglected.

General Management Visits. To obtain a true picture of the progress being made, members of the general management should not visit the research division on well-advertised days, but often should drop in unannounced. Also, they should make it a point to discuss with the various workers, individually, their problems, their hopes, and expectations. Too often, general management gets its picture of research from the research director, who tends to present a distorted view. This criticism probably is limited to a relatively few concerns, however.

Technical Decisions. It should be clearly understood that technical decisions should be made by the technical staff. Frequently, the research director makes technical decisions, as well as those of a business nature. If he is a competent technical man, this is probably all right. But many a research organization has experienced difficulties when the research director is appointed for his business ability and yet makes technical decisions. Sometimes such a man has just sufficient technical knowledge to be "dangerous."

Titles. Some companies have a definite policy of giving only one or two titles in a research organization, for example, the Director and Assistant Director of Research. This creates a great deal of unnecessary ill will and is actually poor business because the members of the organization have no way of identifying themselves in business correspondence as to their particular affiliation—be it as engineer, or salesman, or perhaps on the business staff. In addition, a title can save the man embarrassment if he attends national conventions. If asked his position, he can identify himself merely by giving his title rather than going into a detailed description of his job.

It has been stated that titles are frequently not given because, if a man is found to be in the wrong position, he can be transferred without loss of title and thus with less hurt to its prestige. The author has seen this process in action and he is convinced that the argument is not valid. The loss of a title is not what hurts the man; it is the loss of the job. In addition, in such cases where titles are not given, there often is a tendency for that corporation to lose men to similar positions where a title is available. Perhaps some vanity is tied up with this factor, but if so, it should be recognized.

In the author's opinion, titles should be given to all men from research director to group leader.

Scholars. Research workers, on the whole, are not quite the wild-eyed radicals pictured in the comics. They are generally a pretty nice group of people and fairly easy to get along with, and they are research men for a very special reason. This is the type of work they like to do and they are competent to do it. It does not follow at all that they are competent to *guide* research when it is done by other people, but they may be brilliant research men when left to themselves.

Thus, clearly the appointment of a man to run a group or section or department should not be based on the individual accomplishments of the man or what he has done for the company, but it should be based on the choice of the proper man to run that particular group of people. It is frequently expected that the group leader would be the highest paid man in the group and the department head the highest paid man in the department. But this is not necessarily so, and actually should not be so. A man working in a department might be far more valuable to the company than the department head. Some advanced research organizations recognize that fact and often the department head is a relatively young man who can run a department, but has not himself achieved distinction in research. On the other hand, research men feel that a title comparable with the department head would be a just reward for their labors, and one or two of the progressive companies are considering this matter very seriously. The Monsanto Chemical Company has a very limited group of men who have achieved distinction in research and who are listed as "senior scholars." The salary limitations of senior scholars are not those of a department head. Indeed, they can make as much money as the company feels they deserve, and some of those men are making very handsome salaries.

Punching of Time Clocks. It goes against the grain of most research men to punch time clocks, and yet it is surprising how many research organizations insist on it, even for department heads or the Assistant Director of Research. Actually, the punching of the clock by the senior men of the staff is merely to show the average worker that there is no discrimination; but although no discrimination is shown in that respect, the punching of the clock itself still is repugnant. This is a minor point, but it may create ill-will.

The Stimulation of Invention. In research there should be some tangible way to stimulate inventiveness or ingenuity. This is extremely difficult, and actually the author knows of no system which is completely satisfactory. We all know of systems which work very well in the production field. For example, if a man in the Lincoln Electric Company shows how to cut production time by a certain amount, he is given a percentage of the saving made by the company. In research, however, it is not so easy. If a certain company is expected to design two machines, the sale of one expected to be 50,000 and the other 500,000, and this fact is known ahead of time, a department head would assign a designer, or engineer, to each project. Clearly, then, if both do an equally good job, the income from the one would be expected to be a great deal more than the income from the other, if a bonus is paid on the basis of company returns. But this would not be fair, because in the first place, if both engineers had been reversed in position, they probably would have done equally well. On the other hand, a bonus paid to the entire staff is also not completely satisfactory because non-contributors reap the profit from those who are contributing.

Because of the difficulty of measuring the real output of creative workers, research management may take the easier course of establishing job classifications with fixed price ranges and other similarly leveling expedients. While this may make for easier management, it certainly does not create maximum effectiveness of the group.

Patent Troubles. There often is friction between designers and others as to who should receive credit for patents. Where engineers work as consultants on such projects, to avoid possible jealousy, they frequently step out of the picture and let the designer take full credit. In some companies, it is mandatory for every man to keep a diary showing clearly what he invented, when he did it, and by whom it was witnessed. The author knows from practical experience that it is almost impossible to get the average engineer to keep such diaries and to put in them what should be there. Where such a conflict does arise between two men who claim priority, it is generally expedient for the department head to leave the decision to the patent attorney. Where the department head makes a decision on priority, he generally makes an enemy, or at least he leaves someone in his department with a feeling that the boss is spreading favoritism. When it has been pointed out to various people that they must keep such records, and they have not done so, and as a result of their negligence, they cannot convince the patent attorney of their claims, they have only themselves to blame.

Staff of Machinists. The number and caliber of the machinists should be adequate to keep the demand for parts moving quickly. Too frequently expensive research men must waste time waiting for parts from the shop. Because the machinists in many research organizations are controlled by the production staff, it is easy for the machine shop foreman to build up a backlog of demands, and thus simplify his scheduling problem for men and machines. But it creates considerable trouble in the research and development department.

Minor Irritations. Certain other items which are very distasteful to the research worker crop up periodically. Most of these are of minor character, but they have a major bearing on morale. The following may be mentioned specifically:

1. Proper parking facilities.
2. The purchase of minor equipment.
3. Proper lighting.
4. The minimizing of noise and vibration.

THE INITIATION OF AN IDEA

An idea may come from almost anywhere. The general management may have learned of the doings of a competitor, or may have analyzed the field and decided to proceed in a general direction. Generally, in such instances, a budget is set up to investigate the situation, and the picture reviewed before the money runs out. The investigation may show the idea mechanically feasible but economically unsound, or vice versa, so that periodic reviews are in order.

More frequently ideas are submitted through a suggestion system, which may, or may not, be formally set up. The author's experience indicates that unless a suggestion system is properly controlled by someone with distinct responsibilities in the organization, the suggestion system probably will not be satisfactory. Too often the suggestion system is controlled by someone without the necessary breadth of vision. In addition, the head of the suggestion system should be able to convince a suggester that his idea is not too good with out antagonizing him seriously and without dampening his spirit to help. Certain suggestion systems are in operation, where, at the receipt of a suggestion, a form letter, individually addressed, signed by the Assistant Director of Research, is sent to the suggester indicating that the idea has been received and will be considered. After due consideration, if the idea is obviously not workable, a second form letter is sent out indicating that at the moment the company does not feel that it ought to go ahead with the idea for one of several reasons, which may be that the company is not particularly interested in that field, or that conditions do not warrant putting a lot of money into it, or some other valid reason. Since there are comparatively few of those valid reasons, the form letter becomes rather stereotyped, and after a man has received a half dozen or a dozen of those, he usually throws up his hands and says, "I'm through. I'm sending in no more suggestions." For the suggestion system to operate satisfactorily, the suggester must be given very considerate treatment, called in to explain his ideas, and have a round-table discussion on the suggestion so that if the proposal is no good he will be able to see why without feeling that he is being given a brush-off. The author has gone through this mill on many an occasion in many companies, and in no case has the suggestion system operated to his complete satisfaction.

Where suggestions are sent in by outsiders, it is common practice to set up a separate agency connected with the general management to handle the correspondence before the engineering department sees it, as a precautionary measure. The agency keeps the patent attorneys properly informed.

In general, in such suggestion systems a variable number of the suggestions, up to as high as 90 per cent, can be disposed of immediately as impractical by men of the caliber of a chief engineer. But, of course, such a man ordinarily would not want to spend a large part of his time going over routine suggestions. Therein lies one of the weaknesses, for management may have to go down the line quite a distance to find a man who is willing to do the job, and this man may be nothing more than a glorified clerk. Such men ruin the suggestion system. Thus, the author believes that for a suggestion system to work satisfactorily the suggestions must be examined by a man of some breadth with sound engineering training and with the ability to explain to the suggester that his idea is not acceptable and still have a friend. In some companies a different approach has been adopted with the suggestion system headed by a personnel man who has most of the attributes but not the engineering qualifications; he obtains an engineering analysis from the engineering department when one is called for. As a large part of the suggestions are of a nonengineering type, even in engineering organizations, this might work out satisfactorily.

BALANCING RESEARCH PROGRESS WITH DEVELOPMENT

Where research and development are conducted under the one head, as is frequently the case, an aggressive management may put the development department in a tight spot by weighing progress on a research model and immediately expecting that the development would be simple. The author knows of more than one case where, on the basis of an incomplete research apparatus, the management sold the finished article in quantities before the development department even had considered the subject. Because of the time elements involved and the promise of delivery on a certain date, the development department had an extremely difficult time getting the things done. This, of course, is one way of putting the development department on its mettle, but it is also somewhat questionable.

CHECKING DEPARTMENT

In many progressive organizations today, because of the lack of training in the shop ordinarily acquired by the young machine designer, it is growing more common to have another department set up to check the drawings prepared by the development department and to change them, where necessary, to meet the particular possibilities for that factory, and to simplify, where possible, or to reduce production costs. This particular department ordinarily would be made up largely of men with extensive shop experience and a strong practical viewpoint. They also must be in close touch with the production departments and thus are halfway between development and production. There is a tendency in such a department for men to change designs largely on the basis of their own whims because they feel that a particular design of theirs would be cheaper than that proposed by the previous designer. This type of practice should be discouraged because, in many instances, the original designer knew what he was doing.

In summary, it may be said that many typical defects in research and development organizations have been brought out in the open, with occasional suggestions for solutions.

If a responsive chord has been struck in the minds of any of those reading this article, then it will have served a useful purpose.

A 3,000-Horsepower Gas Turbine Power Plant

J. S. HAVERSTICK
ASSOCIATE AIEE

THE 3,000-horsepower gas turbine power plant described herein has a turbine which is divided into two parts: one drives the compressor and the second drives the load.

The components of the plant are a 3-stage mixed-flow compressor having a pressure ratio of 6 to 1, a 5-stage axial-flow turbine to drive the compressor, and a 3-stage axial-flow turbine to drive the load. Six combustors are located between the compressor and the compressor driving turbine. These components are all arranged along a common axis, and a by-pass is provided around the power turbine in order that the gas-generating portion of the plant may be in operation while the power turbine is at a standstill.

The cycle on which the plant operates is the open cycle, series flow without intercooling, regeneration or reheat, and has design point conditions of 68 degrees Fahrenheit, 14.7 pounds per square inch absolute, inlet air to the compressor, and 1,300 degrees Fahrenheit inlet temperature to the compressor driving turbine.

A complete set of auxiliaries is provided for the plant and includes a main and auxiliary lubricating oil pump, a fuel oil pump, an overspeed trip, a speed governor, a low lubricating oil pressure trip, a tachometer, and free wheeling clutches for the starting drive and turning motor. The auxiliary lubricating oil pump is driven by the turning motor.

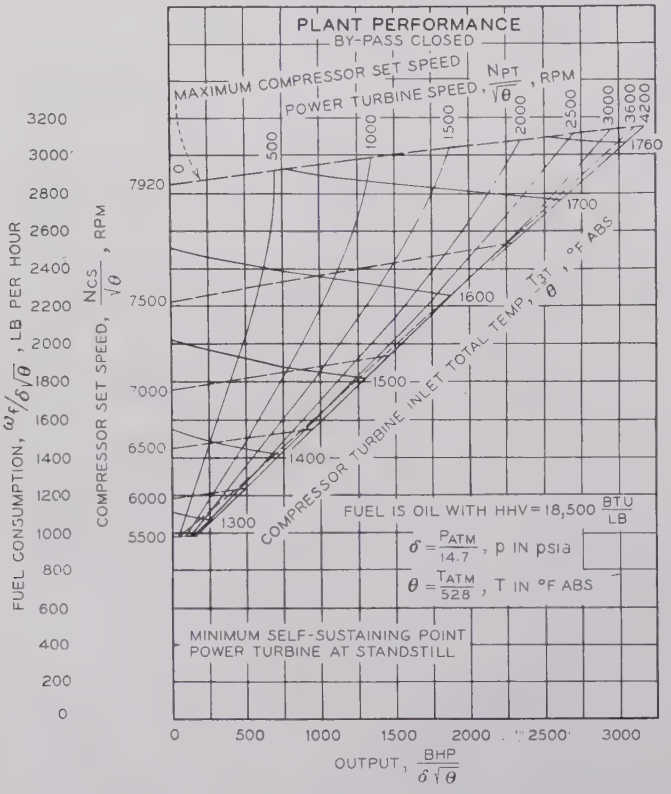

Figure 1. Performance of power plant

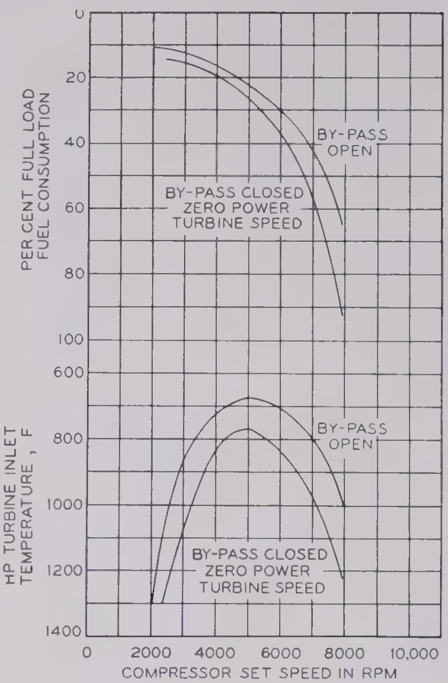

Figure 2. Idling conditions with open and closed by-pass

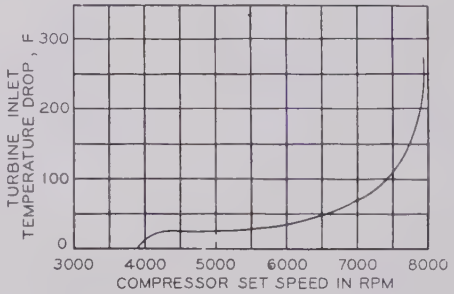

Figure 3. Turbine-inlet temperature drop versus compressor speed from fully closed to fully open by-pass

A composite plot of the performance is presented in Figure 1 in which the variables are output, fuel consumption, power turbine speed, compressor and compressor turbine speed, and compressor turbine inlet temperature. The plot is made for the design ambient air conditions of 68 degrees Fahrenheit and 14.7 pounds per square inch absolute as well as for fuel oil having a H.H.V. of 18,500 Btu per pound and the modifying factors are given for correcting actual operating conditions to these standard conditions. Corrections are given as factors of each variable.

Figures 2 and 3 indicate the speeds and temperatures during idling operation and the turbine-inlet temperature drop versus compressor-set speed.

Digest of paper **49-113**, "A 3,000-Horsepower Gas Turbine Power Plant," recommended by the AIEE Power Generation Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Electrostatic Air Cleaning in the Textile Industry

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DUST COSTS industry billions of dollars annually in spoilage, maintenance, and cleaning bills. Few industries are more familiar with this fact than the textile industry, where spoilage caused by dirt long has been recognized as a major problem.

Figure 1 illustrates graphically the dust particles that abound in the air about us. The larger particles slowly settle or can be removed by mechanical filter systems, but the smaller particles, which are responsible for much damage and human discomfort, were, until comparatively recently, almost impossible to remove. The development of the electrostatic air cleaner, however, has made possible standards of industrial cleanliness heretofore impossible to achieve economically. Experience has shown that substantial monetary savings almost invariably follow the installation of electrostatic air cleaners in textile plants.

DEVELOPMENT OF AIR CLEANERS

The effect of electrostatic fields on smoke particles in air was first observed in 1824. In 1884, Sir Oliver Lodge used electrostatic precipitation in the solution of a lead smelting problem. The first practical installation was made by Dr. Cottrell in 1906. The Cottrell precipitator since has been used extensively in the precipitation of particles from flue gases. Many practical modifications of this precipitator have been designed and marketed.

With a cleaning efficiency of 90 per cent or better, electrostatic air cleaners have reduced spoilage in textile manufacturing to such an extent that they quickly pay for themselves. Besides giving history, operation, and application data, this article points out the health benefits and lint-collecting problems of textile installations.

Not until 1933 was a practical electrostatic precipitator designed in which ozone generation was low enough to permit its use in ventilating systems supplying air for human consumption. This new precipitator was developed at the Westinghouse Research Laboratories.

Westinghouse proved that electrostatic precipitation could remove microscopic air-borne particles which could not possibly be removed by any conventional mechanical filters.

Electrostatic precipitators place an electric charge on air-borne particles, then deposit them on an oppositely charged surface. See Figure 2 for a diagrammatic illustration of this action. While the Cottrell-type precipitator requires 30,000 to 100,000 volts for proper operation, the Westinghouse precipitator places a charge on the air-borne particles in a chamber which is independent from that which collects the particles. By using this 2-stage principle, precipitators requiring a maximum of 13,000 volts have been made possible.

PRECIPITRON COMPONENTS AND OPERATION

The electrostatic precipitator developed by Westinghouse and sold under the trade name of Precipitron, the electronic air cleaner, consists of three essential elements: ionizer, collector cell, and power pack. The ionizer, probably the most important of these elements, places a positive electric charge on air-borne particles without the creation of excess ozone. It consists of tiny parallel tungsten wires spaced in line with parallel tubes at ground potential. A high positive direct voltage on the ionizer wires causes the space between the wires and the rods to become saturated with free positive ions. Particles pick up a surface positive charge as they are blown through this ionized space. After passing through the ionizer section, the air flows between oppositely charged plates in an electrostatic chamber, where the dirt particles are deposited on the negatively charged plates. There they remain until the plates are washed.

The collector section is made up of metal plates parallel to the air flow, the spacing between plates being approximately 5/16 of an inch. Alternate plates are charged at 6,000 direct volts.

The third essential element is the power pack. The most economical power pack so far developed is a modification of the standard voltage-doubling electronic circuit. Two voltage leads are brought out, one supplying 13,000 direct volts for the ionizer section, the other supplying 6,000 direct volts for the collector section. The wattage dissipation is small, being approximately 15 watts per 1,000 cubic feet per minute.

Electrostatic air cleaners of this type are approved by the Underwriters Laboratories, Inc., from the standpoint of both electrical shock and fire hazards, when they have been installed and operated according to the manufacturer's recommendations.

Dirt deposited in the collector cell plates must be removed

Full text of a District paper presented at the AIEE Southern District Meeting, Birmingham, Ala., November 3–5, 1948. Also presented at the AIEE Conference on Electrical Engineering Problems in the Textile Industry, Georgia Institute of Technology, Atlanta, Ga., May 27–28, 1949.

C. H. McWhirter was Precipitron Engineer, and **R. P. Posey** was Industrial Engineer, both with Westinghouse Electric Corporation, Atlanta, Ga., at the time this paper was written. Mr. McWhirter is now Assistant Sales Manager, Anderson Brass Company, Birmingham, Ala.

at regular intervals, usually of three to six weeks duration. The simplest and most economical method of dirt removal yet devised consists of merely spraying the collector cell with water which washes the dirt down the drain.

For small installations, the most economical method of removing this dirt is to hose the cell and ionizer by hand.

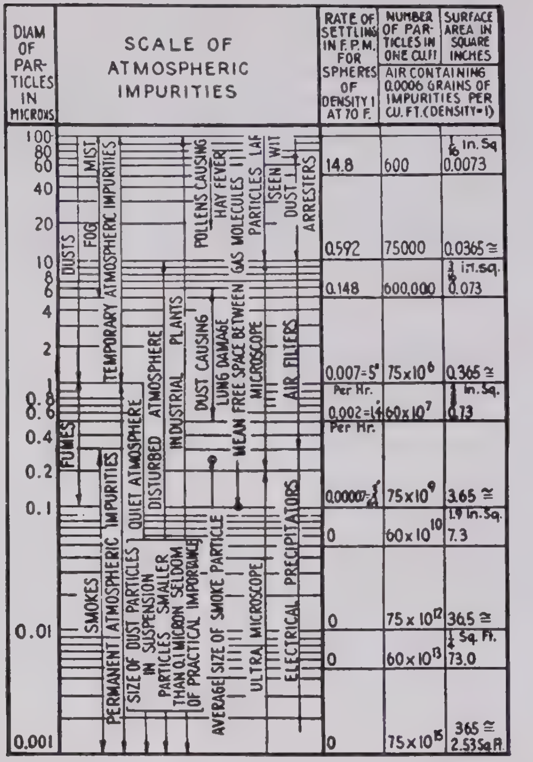

Figure 1. Rate of fall, size, and distribution of air-borne particles

Compiled from Stokes Law

One operator can hose down a 1,000-cubic-feet-per-minute section in approximately ten minutes.

After the collector cells and ionizers have been washed free of dirt, an adhesive is sprayed on which makes it possible for the cell to hold much larger quantities of dirt between washings. The latest development in adhesives is fireproof and nonoxidizing. It may be sprayed on immediately after washing, allowing the unit to be placed back in service in a minimum of time.

For larger installations of 40,000 cubic feet per minute or more, automatic washers and adhesive applicators have been found to be economical. These washers are constructed in such a way that a column of cells can be sealed off, washed, and adhesive applied while the remainder of the cells are in operation.

TESTING ELECTROSTATIC AIR CLEANERS

The introduction of electrostatic air cleaners rendered obsolete accepted test methods conducted on a weight basis. These tests were on artificial dust arrangement, whereas cleaning devices usually are installed to clean normal atmosphere air. A blackness or discoloration test, developed by Westinghouse Research Laboratory engineers with refinements by the National Bureau of Standards, provides greater accuracy, approximates an active particle count, and is made without the addition of artificial dust. Enough air is drawn through sampling tubes from the dirty and clean air sides of the air cleaner to form equal discolorations on filter papers. By comparing the volumes of air, an index is found which gives the efficiency of the cleaner. Electrostatic air cleaners can give an efficiency of 90 per cent or better by such a test, whereas the best mechanical-type filters will give only 10 to 20 per cent efficiency when subjected to the same test. This difference is shown in Figure 3.

TEXTILE PLANT APPLICATIONS

Electrostatic air-cleaner components are manufactured in standard sizes which may be combined to form units of any desired size and air handling capacity.

Electrostatic air cleaners in textile plants can be justified on the basis of improved product quality, reduced maintenance costs, and improved comfort and health conditions. They usually are installed in one or more of three general types of systems:

1. Central systems, which supply entire sections of the plant with air, cleaned and otherwise conditioned in line with plant process requirements. Such an installation is diagrammed in Figure 4.

2. Numbers of small individual forced-air systems frequently are installed in a single large room. Each individual system usually consists of a large ceiling-mounted duct with electrostatic air cleaner, as shown in Figures 5 and 6.

3. Forced-air systems for the drying of yarn require air that is extremely clean. This is particularly true in those installations where air is forced through the yarn packages. Electrostatic air cleaners offer the best and in many cases the only available means of insuring clean air for such applications.

Electrostatically cleaned air is particularly justified for those areas of a textile plant in which the operations of throwing, spinning, and twisting are performed. Each

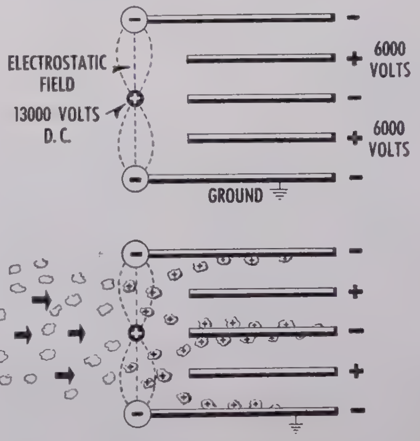

Figure 2. Diagram of electrostatic air cleaner

A foreign particle passing through the field at the left receives a positive surface charge. Carried into the plate assembly at the right, it is drawn out of the air stream to a plate of opposite polarity of these operations involves high-velocity motion of yarn through air, generating high static charges which attract atmospheric dirt particles. These are mostly carbon particles which are twisted into yarn, causing permanent discoloration. In addition both yarn and filament breakages cause loose ends to be thrown about at high velocity, attracting microscopic dirt particles. This results in sections of yarn of greater than average grayness. Only the removal of atmospheric dust, and oil mist as generated by the rapidly moving spindles, by electrostatic air cleaning can reduce effectively such inclusion of dirt within the yarn.

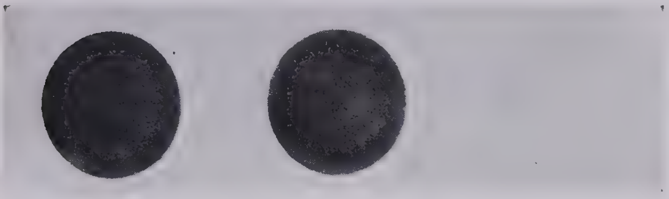

Figure 3. Filter paper through which 10,000 cubic feet of (left to right) uncleaned air, mechanically cleaned air, and electrostatically cleaned air was passed in blackness test

To insure a high quality of finished product, many mills have found that electrostatically cleaned air is necessary in virtually all operations. Contact of the yarn or cloth with contaminated surfaces produces dirt smears which may be difficult or impossible to remove, resulting in an inferior product.

For example, in 1942 a certain southern textile mill produced 1,000,000 yards of rayon-filled crepe, satin, and voile per month with a spoilage of 168,000 yards per month. Upon installation of electrostatic air cleaners, the maximum spoilage dropped to 50,600 yards per month, an increase of 14 per cent in top quality production. The cost of electrostatic cleaners can be amortized quickly under such conditions.

The drying of yarn frequently involves the direct passage of heated air through the yarn package. The package itself acts as a filter; any dirt which may be in this air is retained by the yarn. Consequently, all possible dirt particles must be removed from the process air. The electrostatic air cleaner is the most effective device yet found for such an application, since it will remove atmospheric particles of a size impossible to remove commercially by other means.

An application similar to the package drying described in the foregoing is that in which skeins or packages of yarn are placed in an enclosure through which hot dry air is circulated. Again, dirt may be deposited upon the yarn, causing an inferior product. Cleaning of process air usually is required.

In all of the afore-mentioned applications it should be remembered that the quality desired in the final product is the controlling factor. For example, in materials which will be dyed a dark color there is little point in going to extremes of cleanliness. Only an examination of each material, textile plant, and the losses due to dirt incurred therein, will determine the extent to which the removal of atmospheric dirt particles and the accompanying costs can be justified.

In order to obtain best results, both make-up air and recirculated air should be cleaned. Large quantities of dirt are brought into the mill on the operator's clothing and shoes, hand trucks, and so forth. In addition, high-speed machines usually throw off an oil mist which contaminates the surrounding air. Only cleaning of the recirculated air can remove such contamination. An examination of the conditions and product should be made to determine whether or not it is justifiable to clean all or only the make-up air in any given installation.

To prevent infiltration of contaminated air, a positive static pressure should be maintained by sealing the room

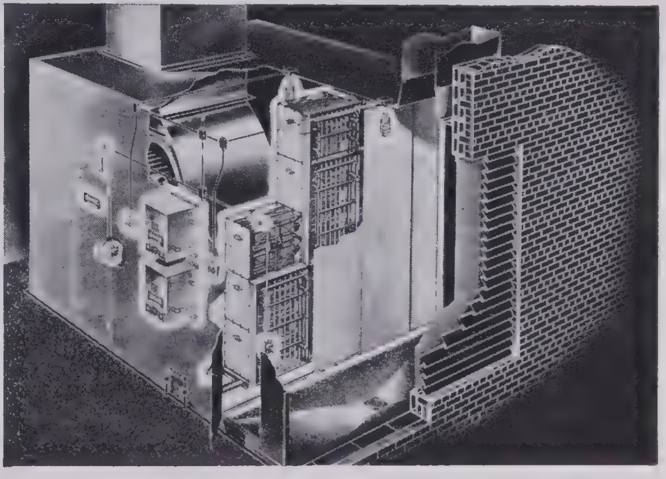

Figure 4. Cutaway view of large electrostatic air cleaner installation showing basic components

Figure 5. Electrostatic air cleaner installed in an individual self-contained forced air system

Several such systems may be installed in one large mill area, as shown in Figure 6

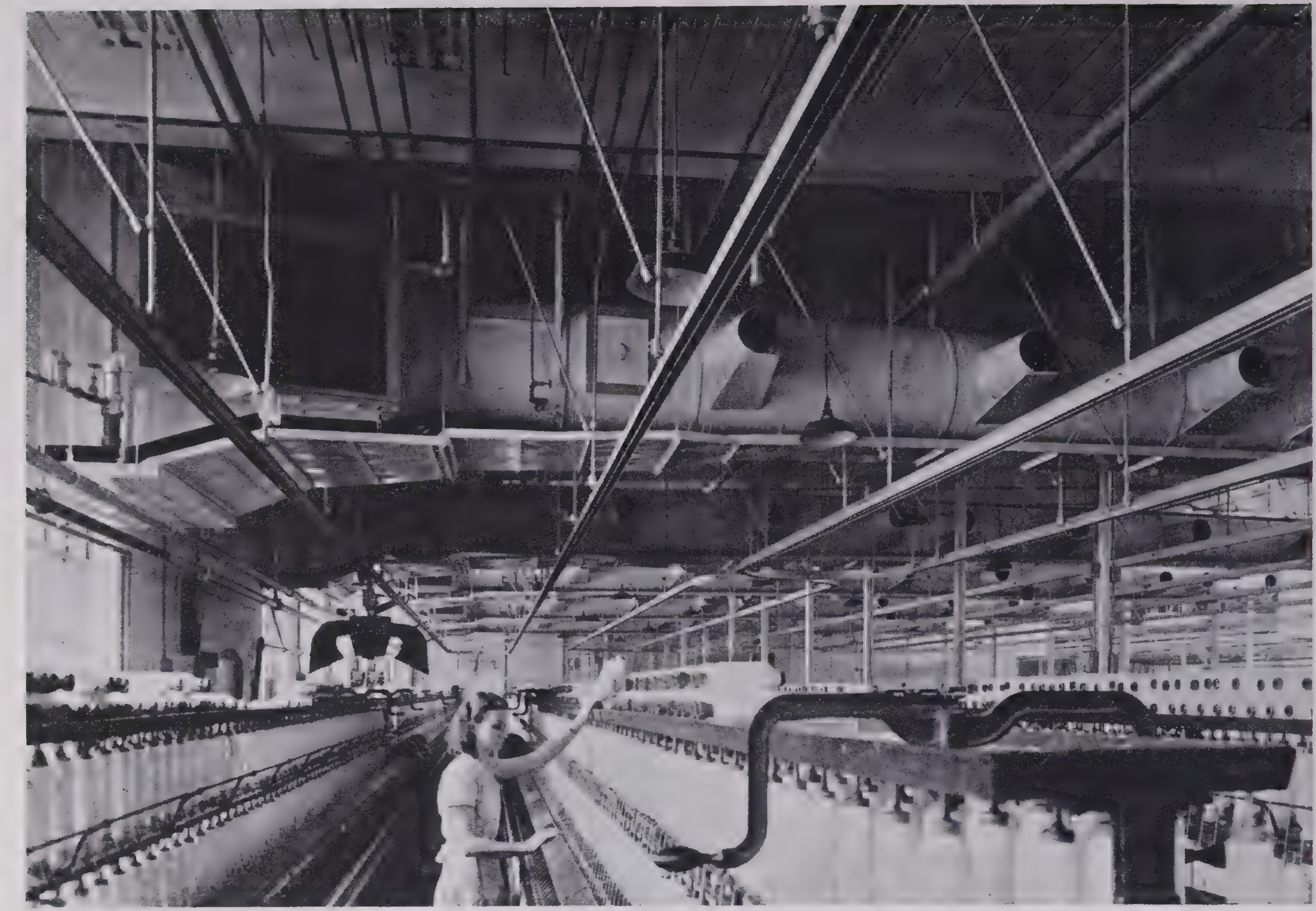

Figure 6. Ceiling mounted ductwork of individual air systems; each duct is a self-contained unit

and allowing the excess air to escape from the room through relief dampers.

REMOVAL OF LINT

The most important problem in textile applications is that of lint, particularly in cotton and woolen mills. Unfortunately, electrostatic air cleaners are not designed for lint removal, as the filaments tend to align themselves perpendicular to the charged plates and as a result may cause intermittent electrical breakdown and arcing between the plates.

This increased arc-over rate reduces the efficiency of operation; and where an extreme arc-over rate is encountered, damage to the equipment may result. Therefore, it is essential to remove lint from the air prior to electrostatic cleaning. For this purpose, a 16- to 20-mesh screen has been found to offer an effective solution. A mat of lint will collect on such a screen and must be removed at frequent intervals in order to prevent blocking of the air flow.

However, since this mat of lint will roll into cylinders with a sweeping motion of a broom or brush, its removal from the screen is not a difficult or lengthy process. Arc-over rates can be reduced by as much as 10 to 50 times merely by the use of a screen ahead of the electrostatic cleaner. It should be noted, however, that arc-overs usually cannot be eliminated completely. An average rate of one arc-over every two minutes is not excessive for the usual large installation.

An air washer through which air must pass before entering the electrostatic air cleaner provides another method for the removal of lint, since the water sprays in such a washer effectively trap the lint. However, great care must be used to prevent the entrance of entrained water droplets into the electrostatic air cleaner. Such droplets will cause excessive arcing, corrosion, ionizing-wire breakage, and other damage.

CLEANER AIR, HEALTHIER WORKERS

Electrostatic air cleaners usually are considered only for the improvement in product quality. However, there is another feature of these cleaners which is not often recognized. This is the reduction of air-borne bacteria and spores which attach themselves to tiny dirt particles as a means of locomotion and existence. These air-borne organisms are removed along with the dirt particles, with consequent reduction in diseases and certain respiratory infections.

A reduction in man-hours lost because of sickness is always reflected directly in plant efficiency, offering additional justification for the installation of electrostatic air cleaners in textile plants.

Vibrating Reed Selectors for Mobile Radio Use

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A new type of signaling system[1] has been developed for mobile radiotelephone service in the Bell System. The basic selection of this system is performed by the use of vibrating reed selectors as described in this article.

Description of Selectors. The vibrating reed selector has magnetic reeds attached to a block to form a small tuning fork, the tines of which are about an inch in length. A polepiece attached to a small magnet is positioned centrally between the ends of the tines. Vibration of the tines takes place when the surrounding coil is energized with the proper voltage and frequency. Two types are used in the mobile radio signaling system; the first as shown in Figure 1 is provided with a contact and is used in the mobile station in groups of four. The other type of selector is similar except that the contact is omitted and this type is used at the fixed station to provide filter characteristics.

The group of four selectors used in the mobile station is operated by a common coil surrounding the four selectors. The selectors in the group are each provided with a plug-type base such that they can be changed as needed. The four selectors operating simultaneously, each of a different frequency, determine the mobile station number.

For common carrier mobile telephone service, it appeared necessary to be able to select any one of 10,000 stations. Such a large number of selections can be achieved in various ways including a combination of 32 frequencies taken four at a time. The 32 frequencies used are all contained in the range from about 350 to 850 cycles.

Performance Characteristics of Mobile Radio Selectors. The suitability of the selectors depends primarily upon their sensitivity at their nominal frequencies, upon their selectivity or discrimination against other frequencies, upon their operate times, and upon their stability with temperature and time. The first three of these factors in turn depend upon the sharpness of tuning or the Q of the vibrating system.

A Q range was chosen to give a constant bandwidth $\left(\text{bandwidth} = \frac{\text{resonance frequency}}{Q}\right)$ of 1.2 cycles for the selectors throughout the frequency range. This requires that the Q vary directly with frequency from about 300 at the lowest frequency to about 670 at the highest. An operate time always under 0.5 second results from these choices under the worst marginal conditions. [The time t required after closing the circuit for the fork tines to reach an amplitude a_t is related to the Q, the resonance frequency f, and the final steady state amplitude A as follows: $a_t = A\left(1\text{-}e^{\frac{-\pi f t}{Q}}\right)$]. The copper slugs shown in Figure 1 are used to provide electromagnetic damping to obtain the proper values of Q.

The sensitivity of the selectors depends upon several factors in addition to Q, such as the force factor, effective mass, contact gap, and the frequency. With four selectors in a common coil, about 0.7-milliwatt available power is required at each frequency to operate the contacts.

The frequency of the selectors can be adjusted to within 0.05 cycle of the wanted frequency by the tuning bars shown in Figure 1. Over a temperature range of −40 to +185 degrees Fahrenheit, the selector frequency changes less than ±0.5 cycles.

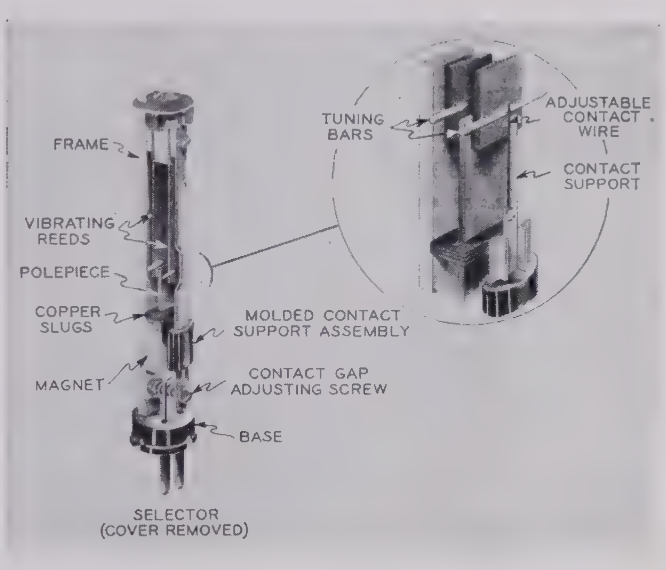

Figure 1. Vibrating reed selector with contact

By bending the tuning bars toward the base of the selector, the frequency is increased, and by bending them away from the base, the frequency is lowered. This effect is the result of changing the effective mass of the reeds.

Performance Characteristics of Filter Selectors. At the fixed station, vibrating reed selectors without contacts are used to provide sharply selective filters. This is accomplished by an impedance bridge circuit in which the vibrating selector is in one arm that is unbalanced by the electrical motional impedance of the selector. For this filter application, the selectors are given a Q in excess of 1,000 by omitting the damping slugs previously described for the mobile station selectors. At 15 cycles or more from resonance of the selector, the transmission loss is greater than 50 decibels.

REFERENCE

1. Vibrating Reed Selective Signaling System for Mobile Telephone Use, **Harold M. Pruden, Daniel F. Hoth.** AIEE *Transactions* (*Proceedings* T999), volume 68, 1949.

Digest of paper **49-99**, "Vibrating Reed Selectors for Mobile Radio Systems," recommended by the AIEE Communication Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Transconductance of Electron Tubes

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ALL OF the functions of an electron tube when used as an amplifier, modulator, frequency doubler, or rectifier, can be formulated in terms of a plate-current-grid-voltage (*i-e*) characteristic expressed as the sum of constant, linear, and square terms in *e*. The characteristics of actual tubes often have such parabolic regions, which can be identified easily on a transconductance-grid-voltage (*g-e*) characteristic by observing that the part corresponding to the parabola on an *i-e* characteristic is a straight line on a *g-e* characteristic.

The *g-e* curve is derived from

$$I_p=\int_{-\infty}^{E_c} g\,de+Gv+\frac{1}{2}\frac{\partial g}{\partial e}\,v^2+\frac{1}{6}\frac{\partial^2 g}{\partial e^2}\,v^3+\frac{1}{24}\frac{\partial^3 g}{\partial e^3}\,v^4$$

where *gde* is the space current at $v=0$, *Gv* is the amplifying component, and the third term is second-order modulation current. Higher terms mean undesirable modulation.

In a pentode and in a triode, when the load impedance is low in comparison with the internal tube resistance, the performance of a tube over a parabolic range can be estimated easily from the *g-e* characteristic, which usually is furnished by the manufacturer. Referring to Figure 1, the fundamental current I_p resulting from an input $P\cos pt$ is $I_p=GP$. The second-harmonic current is $I_{2p}=\Delta g P^2/4\Delta e$. The second harmonic level of an amplifier tube is $H_2=20\log(I_p/I_{2p})=20\log[(E_c-E_0)/P]+12$. The largest possible output current of a frequency doubler occurs when $P=\Delta e/2$ and is $I_{max}=\Delta g\Delta e/16$. The rectified current is $I_{dc}=\Delta g P^2/4\Delta e$. The largest rectified current occurs when $P=\Delta e/2$ and is $I_{max}=\Delta g\Delta e/16$.

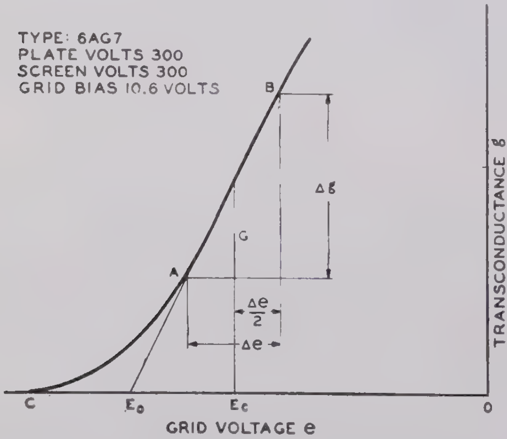

Figure 1. *g-e* **characteristic having principally second-order modulation over part of the range**

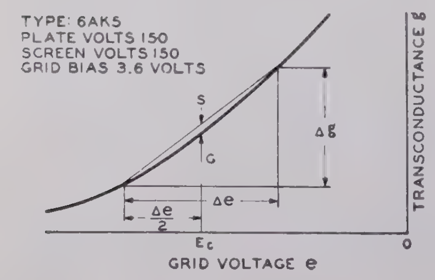

Figure 2. *g-e* **characteristic exhibiting third-order modulation**

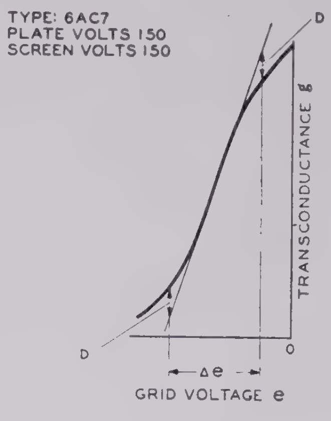

Figure 3. *g-e* **characteristic exhibiting fourth-order modulation**

In a modulator, when the input voltage is $P\cos pt+Q\cos qt$ the useful output current is $I_{p\pm q}=PQ\Delta g/2\Delta e$. The maximum possible current occurs when $P=Q=\Delta e/4$ and is $I_{max}=\Delta g/32\Delta e$. When the modulator is used as a detector, *P* is small and $Q=\Delta e/2$. Then, $I_{p\pm q}=P\Delta g/4$ and the conversion transconductance is $G_c=\Delta g/4$.

In cases where the *g-e* characteristic departs from a straight line, higher-order modulation products are generated. If third-order modulation is present, the *g-e* characteristic usually sags in the middle by the amount *S* (see Figure 2).

Then, the effective transconductance becomes a function of the input voltage, $G_e=G+S(P/\Delta e)^2$. At an input $P=\Delta e/2$, this is $G_e=G+S/4$. There will be present in the output a third harmonic. Its level will be $H_3=20\log(G/S)+40\log(\Delta e/P)+10$. At an input $P=\Delta e/2$ this reduces to $H_3=20\log(G/S)+22$.

If fourth-order modulation alone is present, the *g-e* characteristic has an inflection point. Referring to Figure 3, the fourth-harmonic level of an amplifier will be $H_4=20\log(G/D)+60\log(\Delta e/P)+12$. For $P=\Delta e/2$, this reduces to $H_4=20\log(G/D)+30$. A rectifier now does not obey the square law. The error is $\Delta I_{dc}/I_{dc}=3DP^2/\Delta g(\Delta e)^2$. A frequency doubler is subject to the same error. In a modulator, the conversion transconductance is not constant $G_c=\Delta g/4+3D/8+3DP^2/2(\Delta e)^2$. In a heterodyne oscillator, a second harmonic appears in the modulator output. Its level for the maximum output is $H_2=20\log I_{p-q}/I_{2p-2q}=20\log(\Delta g/D)+14$.

Digest of paper **49-106**, "Transconductance as a Criterion of Electron-Tube Performance," recommended by the AIEE Electronics Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Not scheduled for publication in AIEE *Transactions*.

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Matching McNary Electrical Characteristics With Bonneville Transmission System

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Low-reactance powerhouse equipment would increase costs for the McNary Dam installation by $3,200,000. Combining cost analysis with network analyzer studies, however, showed that this increase would be more than offset by transmission-line savings. Over-all savings of $7,000,000 are estimated.

CARRYING out the planned orderly development of the Columbia River for power, navigation, reclamation, and flood control purposes, the Federal Government has selected the McNary Dam site as the next major project. The site is located on the main stem of the lower Columbia River between the present Bonneville and Grand Coulee dams and near Umatilla, Oreg. The dam will produce slack water 59 miles up the river to a point 32 miles above the mouth of the Snake River. The ultimate installed capacity of the power plant will consist of 14 generating units rated at 73,684 kva each at 95 per cent power factor, thereby permitting the plant to generate 1,127,000 kw at rated power factor, including an overload of 15 per cent which the generating units are being designed to handle. Present plans call for the installation of 10 to 12 of these units, with the balance of the machines to await the development of other up-stream plants which will provide sufficient increased storage reservoir capacity to justify further installation.

The McNary Project, being constructed on a navigable stream with important navigation as well as power features, will be under the authority of the Corps of Engineers, United States Army, and hence will be designed, constructed, and operated by that agency. The Bonneville Power Administration has the responsibility of transmitting and marketing the power and providing for payout of costs of the transmission system and those costs of the generating station chargeable to power purposes for all Federal multipurpose projects within the Columbia River Basin. Hence, the Administration will receive the power generated at McNary and will provide the transmission network necessary to deliver this power to the distant load centers. It is vitally interested in the cost features of the dam and generating plant which are properly chargeable to power.

The engineers of both Federal agencies recognized that the electrical characteristics built into the generating and transformer equipment at McNary would have a great effect upon the over-all economy and the operating characteristics of the complete system, and that close cooperation between the two agencies would obtain a combination of generating plant and transmission system which would serve the needs of the area adequately and total the least cost to the Federal Government. Accordingly, the agencies have worked closely together to this end. The Corps of Engineers requested the Bonneville Power Administration to study and recommend the characteristics for the generators and transformer to be installed at McNary. This request resulted in the following:

1. The generators should have a transient reactance not greater than 32 per cent on the generator rating of 73,684 kva at 95 per cent power factor.

2. Continuous damper windings should be provided that will give a ratio of X_q''/X_d'' not greater than 1.1, as determined by tests at air-gap excitation corresponding to rated current, power factor, and voltage, with X_q'' determined from X_2.

3. The exciter response should be not less than 1.5.

4. The transformers should have a reactance of not more than 8 per cent on the bank rating of 169,500 kva with two generators connected to a bank.

Following these recommendations, cost figures were compiled by the Corps of Engineers which indicated that the transient reactance for minimum-cost machines for the McNary installation would be 44 per cent on a base of 73,684 kva. With an additional installed cost of $1,550,000 for 14 machines, it would be possible to obtain machines having the recommended transient reactances of 32 per cent. Similarly, reactances for minimum-cost transformers, each bank of which is designed to carry the output of two generators, would be 13.5 per cent on a base of 169,500 kva, but this value could be reduced to as low as 8 per cent with an additional cost of $590,000 for seven such banks of transformers. Other additional costs would be incurred with low-reactance units because of the greater physical size of such equipment. These costs included greater investment in the powerhouse and crane, and an equivalent capitalized value due to lowered generator efficiency. The total increased cost for reduced reactances for both machines and transformers was calculated to be $3,200,000 including all these factors, as compared with the cost of minimum-cost equipment. Obviously, a strong justification was needed for the expenditure of $3,200,000 for special characteristics for the McNary generators and transformers; therefore the

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Essentially full text of paper **49-209,** "Matching Electrical Characteristics of McNary Generators and Transformers with Bonneville Power Administration Transmission System," recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Pacific General Meeting, San Francisco, Calif., August 23–26, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Acknowledgment is given to R. C. Schuknecht and L. K. Fisher, Portland office, Corps of Engineers, United States Army; and to E. C. Starr, Consultant, Bonneville Power Administration, for their excellent assistance and co-operation in arriving at a satisfactory solution to this important problem.

Corps of Engineers requested the Bonneville Power Administration to prepare this justification.

SYSTEM STUDIED

The most satisfactory measure of the benefits to be gained from lower reactance facilities at McNary is a comparison of the maximum power which can be transmitted over the power system with high-and low-reactance terminal equipment, and a determination of what additional transmission facilities must be installed with high-reactance equipment to obtain the same stability as with low-reactance equipment. These factors were obtained through use of the Administration's a-c network analyzer.

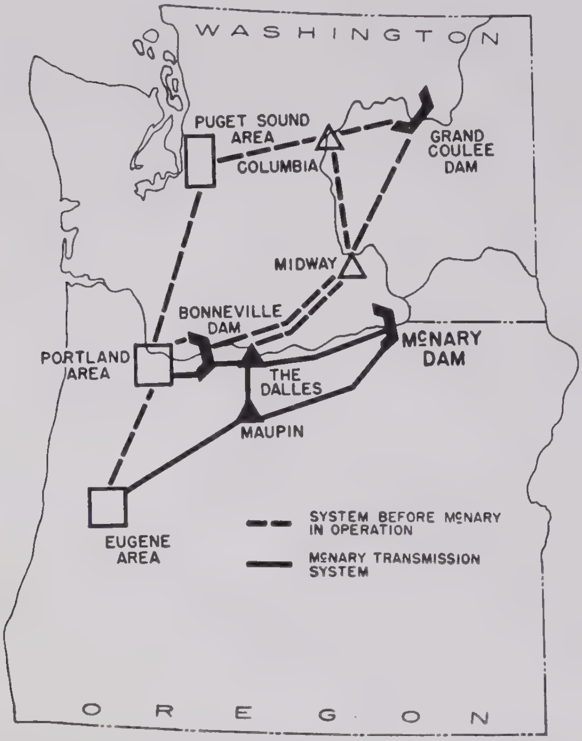

Figure 1. Geographical location of McNary Dam and associated transmission system

In making the study, a simple 3-machine equivalent system was devised, which would be expected to act reasonably like the actual system. This system is shown as set up for various load studies in Figures 2, 3, and 4. The major components of this simplified system are indicated geographically in Figure 1. Generator and transformer characteristics are given in Table I. This system consisted of the McNary generators and equivalent receiver-end machines at Portland and Eugene, with the latter two equivalent machines representing the composite effect of all generators in the two areas, which experience has shown will act as a group for faults which are far removed from these areas. The transient reactances and inertia factor selected for these receiver-end machines are an approximation of the weighted average for all generators and synchronous condensers considered. The reactances of the receiving-end transformers also were based on average values of all transformers in the area, with an allowance for the reactance of the distribution and transmission system between the actual generating plants and the high-voltage receiving-end busses at Portland and Eugene.

The transmission network consisted of essentially three 200-mile 230-kv lines from McNary to the Portland area, utilizing 800,000-circular-mil copper equivalent conductor, with a sectionalizing station at The Dalles, 110 miles from McNary; two 105-mile 230-kv lines utilizing this same conductor from McNary to Maupin, and one similar line from Maupin to the Eugene area, a distance of 140 miles. A 40-mile 230-kv line connects The Dalles and Maupin, and the equivalent impedance between the Portland and Eugene areas represents the impedance of transformers and 115-kv lines between the 230-kv busses in these areas. From a study of the normal operating power factors of the individual generators in the Portland and Eugene areas and including the effects of synchronous condensers, it was possible to approximate the power factor at which the equivalent generators used in the study should operate. The power factor of the receiving-end loads then was adjusted so that the proper generator power factors were obtained on the equivalent network.

This process might be considered comparable to the adding of static capacitors on the system for the purpose of limiting the reactive requirements on the generating plants. Admittedly, the simplified network cannot be expected to perform exactly as the actual system, but, as will be pointed out later, the net error should be small in view of the comparison method used to obtain results.

In previous studies it had been established that the most severe fault for the system would be near McNary on one of the lines to The Dalles, in spite of the fact that the circuits between The Dalles and Portland would be somewhat more heavily loaded than those between McNary and The Dalles. Accordingly, a 3-phase fault was assumed at McNary on one of the lines to The Dalles. The faulted line was assumed to be cleared simultaneously at both ends in $3^1/_2$ cycles and reclosed at both ends in 21 cycles through the use of microwave relaying and high-speed reclosing. This

Table I. Generator and Transformer Characteristics

Generator Characteristics	Transformer Characteristics
McNary*	
44 per cent X_d' on 73.68-megavolt-ampere base, $WR^2=186\times10^6$ pound-feet squared	7 units at 170 megavolt-amperes each (for two generators)
32 per cent X_d' on 73.68-megavolt-ampere base, $WR^2=219\times10^6$ pound-feet squared	$X=8$ per cent to 13.5 per cent on 170-megavolt-ampere base
14 units at 70 megawatts, 73.68 megavolt-amperes, 95 per cent power factor	
Maximum loading, 1,128 megawatts (15 per cent overload)	
Portland Area	
$X_d'=40$ per cent on 1,500-megavolt-ampere base, $H=4$	$X=30$ per cent on 1,500-megavolt-ampere base (includes equivalent system)
Eugene Area	
$X_d'=40$ per cent on 500-megavolt-ampere base, $H=4$	$X=30$ per cent on 500-megavolt-ampere base (includes equivalent system)

* WR^2 includes estimated values for generator plus water wheel.

clearing and reclosing time is about the ultimate which reasonably might be expected by the time the McNary generation is installed.

PROCEDURE

The first step in the procedure was to obtain a load-flow diagram of the system using low-reactance generators and transformers with the 14 machines at McNary loaded to 1,128 megawatts, including the overload capability of 15 per cent, then to check the transient stabliity of the system for the fault assumed. The result of this procedure is shown in Figure 2, which was transiently stable for the fault assumed with a maximum swing between machines of 104.5 degrees.

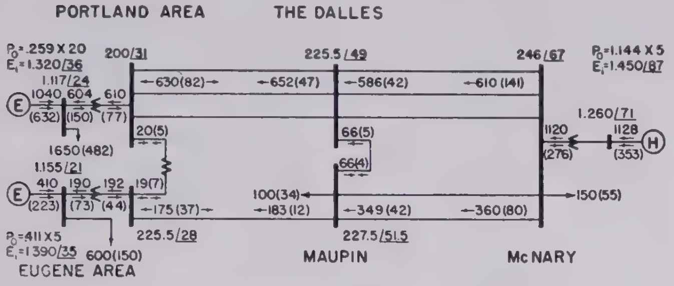

Figure 2. Equivalent system, basic transmission system, low-reactance equipment

McNary reactances $X_d' = 32$ *per cent on 73.68-megavolt-ampere base*
X transformer $= 8$ *per cent on 170-megavolt-ampere base*
1,128-megawatt output at McNary
Maximum swing $= 104.5$ *degrees*

It will be demonstrated later that this power swing was very close to the transient stability limit, since an increase in loading of the order of one per cent of the output of McNary would result in instability. In Figure 2 the output of McNary was 1,128 megawatts. The three McNary–The Dalles lines carried 610 megawatts, and the three lines from The Dalles to Portland carried 652 megawatts. The power factor of the output of the Portland and Eugene area equivalent generators was held at 85 per cent and 88 per cent, respectively, and the voltage at the high-side bus at McNary was held at 246 kv, which value had been established previously by other network analyzer studies of the original system.

The second step in the procedure, starting with the identical system as used in the preceding paragraph, was to substitute high-reactance transformers and generators at McNary for the low-reactance equipment and determine how far down the loading on McNary must be dropped to gain the same degree of system stability as in Figure 2. All local loads and receiver-end generators were held constant, except that the local load at the Portland area was varied to control the output of the McNary plant. Assuming the same fault, clearing time, and reclosing as previously, it was found that the output at McNary had to be decreased from 1,128 megawatts to 1,012 megawatts, if high-reactance equipment is installed at McNary and no new transmission lines are constructed. This loading had a maximum swing of 102.5 degrees, essentially the same as for that of Figure 2.

Assuming identical transmission systems, the permissible loading of the generating station was decreased 116 megawatts or 10.3 per cent by the use of high-reactance equipment as compared to the use of low-reactance equipment. The permissible loading on the transmission system from McNary to Portland and Eugene was decreased from 978 megawatts to 862 megawatts by the use of high-reactance equipment, a decrease of 11.9 per cent.

The next phase of the problem was to determine what additions must be made to the system so that the generating station can be loaded to the 15 per cent overload value of 1,128 megawatts with transient stability if high-reactance equipment is installed.

Accordingly, a fourth line section was assumed installed between The Dalles and Portland, the most heavily loaded portion of the system, and the McNary plant was loaded to 1,128 megawatts by increasing the local load at the Portland area. The resultant loading is given in Figure 3. For the fault, clearing time, and reclosing assumed previously, this system was insufficient as it was unstable.

Then a fourth line was assumed installed between McNary–The Dalles–Portland area, and the system again balanced to 1,128-megawatts output of McNary as shown in Figure 4, using essentially the same substation loads as in Figures 2 and 3. This loading proved to be transiently stable with a maximum swing of 101.5 degrees.

An additional study was made to demonstrate that the differences in the angle of maximum swing obtained for loadings corresponding to those preceding which are stable

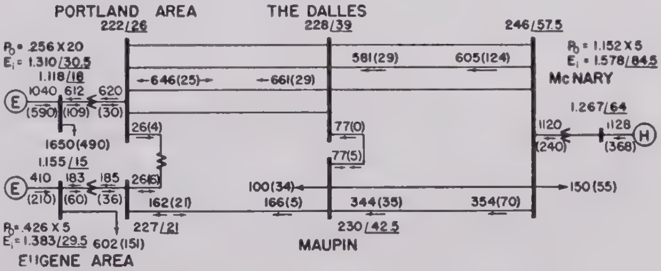

Figure 3. Equivalent system, additional transmission line between The Dalles and Portland, high-reactance equipment

McNary reactances $X_d' = 44$ *per cent on 73.68-megavolt-ampere base*
X transformers $= 13.5$ *per cent on 170-megavolt-ampere base*
1,128-megawatt output at McNary
System unstable

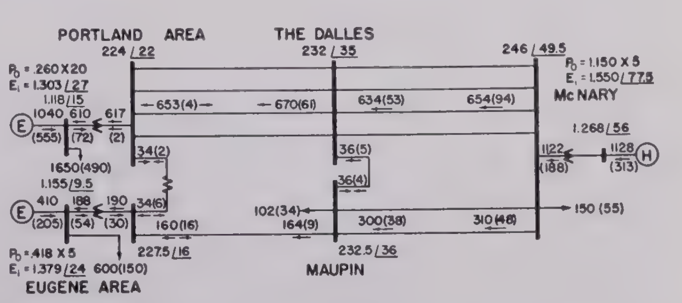

Figure 4. Equivalent system, additional transmission line between McNary and Portland, high-reactance equipment

Reactances and output as given in Figure 3
Maximum swing $= 101.5$ *degrees*

do not represent any significant difference in system stability, and that these loadings are very close to the transient-stability limit. To prove this the system loading shown in Figure 4 was increased by only 20 megawatts in the Portland area. This load increase amounts to less than two per cent of the output of McNary, but this slight addition resulted in a change from a stable condition with an angle of maximum swing of 101.5 degrees to an unstable condition. This indicates that the preceding stable system loadings are such that the system stability is practically identical and very close to the transient stability limit.

From these load studies it was concluded that if high-reactance equipment is purchase for McNary, it will be necessary to build an additional 230-kv line from McNary to The Dalles to the Portland area, a distance of approximately 200 miles.

SUMMARY OF NETWORK ANALYZER STUDIES

1. With three 230-kv lines between McNary and the Portland area and low-reactance equipment at the generating station, the system is transiently stable for the full 1,128-megawatt output of McNary including the 15 per cent overload.

2. With the same transmission system as the foregoing but with high-reactance equipment at the generating station, the output of McNary must be reduced to 1,012 megawatts to assure transient stability, a decrease of 116 megawatts or 10.3 per cent of the total output of the generating station. The corresponding decrease in the permissible loading on the McNary–The Dalles lines was 11.9 per cent.

3. To assure system stability for 1,128-megawatt output of McNary using high-reactance generators and transformers, it will be necessary to construct a fourth 200-mile line from McNary to The Dalles to Portland.

4. System loadings in all these cases are essentially identical from the point of view of transient stability and are very close to the transient-stability limits.

5. While the method used in the individual studies may have inherent error due to over-simplification and inability to get exact equivalents of the receiving-end portion of the system, the conclusions of the study are formed by obtaining incremental capability of the system through comparison of two or more studies; therefore possible inaccuracies should almost all cancel out.

COST ANALYSIS

A cost analysis of the system was made for two cases, the first having low-reactance equipment and one less transmission line as shown in Figure 2; the second having reactance corresponding to minimum-cost generators and transformers but with the additional transmission line as shown in Figure 4.

In order to minimize any possible inaccuracies, the method of obtaining incremental costs in the transmission system and in the generating station was used to determine the benefit-to-cost ratio. A summary of this cost study is given in Table II. Information for costs in the generating station was supplied by the Corps of Engineers and included factors for increased powerhouse and crane cost and capitalized values of energy lost due to reduced machine efficiencies when low-reactance equipment was being considered. For the transmission system a capitalized value for the increased transmission losses caused by the use of one less line was included.

The results of this study indicated a very large saving in the transmission system and a net over-all saving to the government of over $7,000,000 through purchase of low-reactance equipment at McNary, even though the value of increased equipment cost would be over $3,000,000. The benefit-to-cost ratio is of the order of 3.2, which would indicate that from an economic standpoint still lower machine and transformer reactances could be justified. This was considered; however, physical size of the equipment became a determining factor. For example, transformers with eight per cent reactance are the largest which could be conveniently shipped as a unit—any larger size would have to be assembled in the field. There are physical limitations in the generating unit also which resulted in the manufacturers recommending against going to any larger size. However, the high ratio of benefits to cost obtained through lowering the reactances of the McNary generators and transformers does appear to justify fully the obtaining of low-reactance equipment for this plant.

Table II. Cost Analysis

Transmission Line		
Cost of additional 230-kv line with four circuit breaker positions in lieu of low-reactance powerhouse equipment at 1948 cost values using 800,000-circular-mil equivalent copper conductors		
McNary–The Dalles section—110 miles at $48,000 per mile—includes right-of-way and clearing	$5,280,000	
The Dalles–Portland section—90 miles at $62,000 per mile—includes right-of-way and clearing	5,580,000	
Four 230-kv circuit-breaker positions at $218,000	870,000	$11,730,000
Subtracting capitalized value of additional line losses by having one less line in service with incremental loss of peak firm and peak secondary power from Figures 2 and 4=12,400 kw. Average value per peak kilowatt incremental loss: $5.67 per kilowatt-year. Interest, replacement, and operations and maintenance 4.8 per cent. 12,400×5.67/0.048		1,470,000
Net system savings available for reducing powerhouse equipment reactances		$10,260,000
Powerhouse Equipment		
Increase cost of 14 generators because of reduced reactance and increased installation cost	$1,550,000	
Increased cost of seven transformers because of reduced reactance and increased installation cost	590,000	
Capitalized value of lower generator efficiency due to low-reactance generators. Estimated reduction in efficiency, 0.4 per cent. Value at $185 per installed kilowatt. $185×70,000×14×0.004	730,000	
Estimate of increased powerhouse and crane cost due to low-reactance equipment	300,000	
Increased cost chargeable to low-reactance equipment		3,170,000
Net Over-all Saving		$ 7,090,000

CONCLUSIONS

It is believed that the results of this study will be of major interest to the industry, for while most engineers agree that low-reactance equipment should be used, the question of justifying such equipment economically nearly always presents a major problem. It is recognized that each project becomes an individual problem to be studied in accordance with the peculiar conditions arising, for it is the combined system, including both transmission and generation, which must be studied. This article presents, in our opinion, a very satisfactory method of investigating and solving this type of problem. We believe this method can be applied successfully in many cases.

An Analysis of Magnetic Recording

C. S. THOMPSON

MAGNETIC recording is the process of transforming electric impulses, varying with time, from an electric circuit to a succession of fixed magnetic fields, varying with distance, along a filament of ferromagnetic material. The magnetic-field space variations are closely proportional to the time variation of the original electric impulses for good recording. The transformation of electric impulses to variations in magnetic field along a wire or tape is accomplished by passing the ferromagnetic wire or tape across an air gap in the iron core of an electromagnet energized by current impulses passing through the coil of the electromagnet. Passing the magnetized wire or tape across the air gap of a similar electromagnet causes a voltage to appear across the terminals of the coil of this second electromagnet. The first electromagnet, used for impressing the electric impulses upon the magnetic recording medium, is called the recording head. The second electromagnet referred to, used for retranslating the stored magnetic impulses into electric impulses, is called the play-back head.

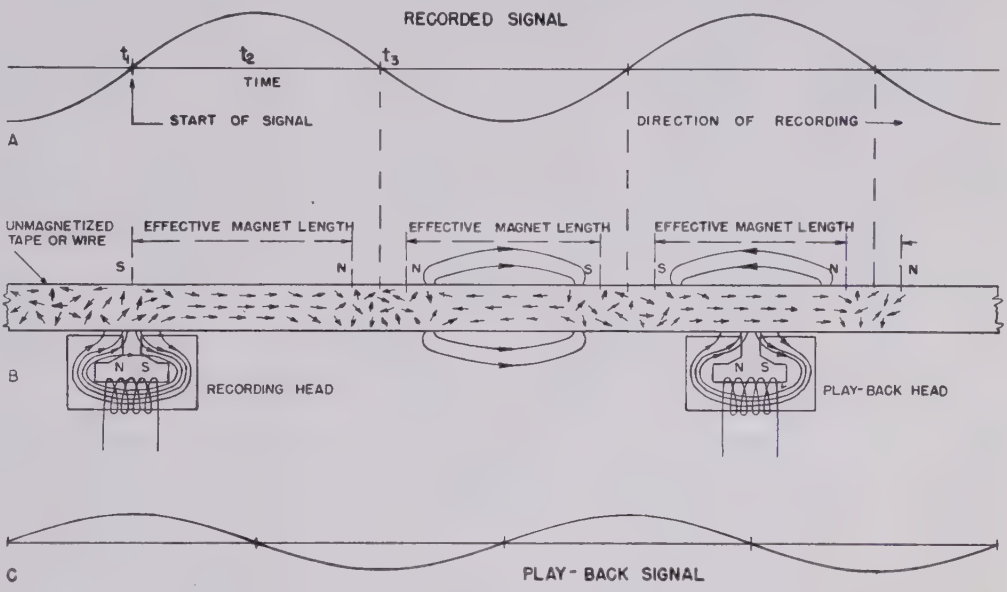

Figure 1. Diagram illustrating theory of magnetic recording

Figure 1*A* shows the signal to be recorded as a sine wave of current in the coils of the recording head; Figure 1*B* shows an enlarged view of the recording wire or tape. The small arrows represent symbolically the alignment of the so-called "molecular magnets." Immediately below the wire or tape, the recording head is shown with flux lines threading its core. The bottom leg of the core is surrounded by an energizing coil. The pole tips are marked with an assumed polarity indicated by the symbols *N* and *S*. The play-back signal produced by this passage is shown in Figure 1*C*.

Among the most important considerations are those of the magnetic characteristics of the recording medium itself. For each reversal of polarity, the medium is subjected to magnetic changes described by the familiar hysteresis loop. Because of the nonlinear characteristic of the hysteresis loop, the relation between the impressed magnetic field strength, H, and the residual induction, B_r, suffers a severe distortion unless a so-called biasing magnetic field of a constant frequency much higher than the signal frequency is impressed simultaneously with the signal to be recorded.

The various component characteristics influencing the over-all fidelity of a magnetic recording system are

1. Magnetic skin effect in the magnetic circuit of the recording head.
2. Magnetic skin effect in the play-back head.
3. Influence of the air-gap length in the play-back head.
4. Demagnetization effect.
5. Recording circuit impedance.
6. Play-back circuit impedance.

Experimental evidence shows that magnetic skin effect as a function of core lamination thickness is more important than had been believed previously. High-frequency cut-off can be raised considerably by using very thin laminations. In this connection, The Franklin Institute, under contract to the Special Devices Center, United States Navy, is constructing a series of recording and playback heads to determine the optimun thinness of laminations.

The criteria for judging the operating excellence of a magnetic recording system are the frequency response curves of the fundamental frequency, harmonic distortion, and the noise content. The operating factors influencing the output characteristics are the frequency and amplitude of the bias current, the frequency and amplitude of the signal current, the wire velocity, the air-gap length, the characteristics of the recording medium, and the characteristics of the recording and play-back heads.

Digest of paper **49-107**, "Application of Experimental Test Procedures and Methods of Analysis of Results to Research Problems in Magnetic Recording," recommended by the AIEE Communication Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Equivalent Circuits for Power-Flow Studies

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NETWORK ANALYZER STUDIES of power-flow conditions on large interconnected systems frequently require preliminary simplification and reduction of the network because of the limited number of analyzer circuits and sources available. Even in smaller systems which do not exceed the capacity of the analyzer being used, it is sometimes desirable to represent in detail only a portion of the system, simplifying the remainder by use of equivalent circuits for the purpose of speeding up studies on the portion of primary interest. Simple equivalent circuits can be devised for extensive power networks by adopting the viewpoint that in power-flow studies the system generation and loads approach, as an approximation, constant-current quantities. The network being simplified may contain numerous loads and generators, but the equivalent circuit derived by this method retains the identity of only the tie-line terminals or points of interconnection with the detailed setup. The line network of the reduced system is replaced by an equivalent mesh network between retained tie-line terminals. If m is the number of such terminals, this mesh network in general will consist of $m(m-1)/2$ branches. The effects of the suppressed generators and loads are reproduced by an equivalent generator or load at each tie-line terminal. An equivalent circuit of this type can be derived for a given system either by analytical methods or by simple tests on an analyzer setup of the complete network which is to be reduced. The equivalent circuit is flexible in that any schedule of internal generation and loads can be reproduced readily without the necessity of repeating the reduction or of making additional tests.

The equivalent loads and generators are determined by application of the principle of superposition. Each generator and load in the reduced network contributes to the equivalent net source or load at each tie-line terminal. In treating loads and generation alike as current sources, the distinction between them is merely a matter of relative phase position of the currents. The contribution of one suppressed source at the retained terminals can be determined by impressing unit current at that bus with all other sources open (loads, generators, and capacitors) and with the tie-line terminals short-circuited to neutral. The fractions of unit current input which leave by way of the several short-circuited tie-line terminals are treated as distribution factors to apportion at the retained terminals a scheduled loading of the bus which is energized. Similar distribution factors are determined for each load and generator bus in the reduced network. When all generation and load is reflected to the tie-line terminals in this fashion, the actual line network is replaced by an equivalent network of transfer impedances between the retained tie-line terminals.

Some of the assumptions, limitations, and additional features of the equivalent circuit method are summarized briefly in the following.

1. In most power-flow studies the bus voltages and angles in sections of the system which might be replaced by equivalent circuits do not vary widely. An initial, normal set of voltages and angles can be taken into account accurately and the assumption made that subsequent variations in these can be neglected.
2. Synchronous condensers, static capacitors, and line charging capacitance may be treated as separate sources of reactive power or combined with nearby loads or generation.
3. It is assumed that loads and generation in the reduced system operate at a fixed schedule of real and reactive power loading. The reactive power output of generators and synchronous condensers may be subject, in actual system operation, to wide variations, thus introducing a serious departure from the constant-current assumption. The representation of variable reactive power generation is simplified if busses of known, fixed voltage are chosen as the retained terminals. Then, only the real-power component of the equivalent sources need be determined.
4. Effects of off-nominal transformer tap settings in the reduced system can be reproduced approximately in the equivalent circuit.
5. A d-c board can be used to determine the equivalent line network and distribution factors if it is assumed that transformer taps are on nominal ratio and impedance angles are uniform.
6. The net equivalent sources can be determined by an alternative method involving network analyzer measurements on a setup of the complete network. To obtain the net equivalent sources, normal-flow loadings on tie lines are combined with the circulating flow appearing in the equivalent mesh network as a result of the same normal-flow terminal voltage and angle differences.
7. If the equivalent circuit calls for several analyzer generator units and they are not available, further reduction can be made, at the expense of additional line units, to evolve an equivalent circuit requiring only one analyzer power source.
8. In applications to power-flow studies, the methods are not exact. The degree of approximation involved depends on the special conditions and characteristics associated with individual systems.

Practical experience with this type of equivalent circuit in system studies has yielded good results. The methods used seem to be well suited for representing intercompany ties.

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A Telephone Number Recorder

F. HINTON F. E. PLANER

An instrument is described for use on the terminals of a telephone to provide a subscriber with a printed record of the telephone numbers of callers who have telephoned during his absence. The instrument is simple to install and operate, and is considerably less complex and costly than an automatic spoken-message recorder.

THE WISH to record telephone calls made during the subscriber's absence is a very old one. The problem has occupied inventors since the time the first public telephone systems were installed, as is proved by the number of patent applications in this field. The various devices proposed for this purpose have in common the use of a recorder of the type employed in dictaphones, together with an arrangement for playing back to the caller a short recorded announcement to inform him of the absence of the called subscriber and of the fact that a recording will be made of any message spoken. The devices usually contained various combinations of switches and relays to ensure the correct sequence of events in the cycle of operation.

Owing to the many technical difficulties which have had to be overcome in their design, recorders of this type have not been introduced into practice until quite recently. These instruments, installed in limited numbers in various parts of the world, have aroused interest everywhere. Their recording, play-back, and announcing systems and associated electronic amplifying circuits, together with the relatively complex switching arrangements required, have led to a machine which is of considerable size and weight, and whose cost or rent would appear to be considerably beyond the reach of the average telephone subscriber. Therefore, these instruments are used mainly by businesses and large stores desirous of affording a day and night service for the ordering of goods, and so on, as well as by doctors who may wish to give their patients the facility of recording messages, while they are away from their offices.

To overcome the difficulties arising from the complexity, high cost, and large size of automatic recording instruments of this type, the task of solving the problem of the "absent subscriber device" on an entirely new principle was begun. The new approach was based on the consideration that in the majority of instances, it is sufficient to record the telephone number of the caller, instead of a spoken message. Thus the subscriber is presented, on his return, with a record of the telephone numbers of the various callers who have telephoned during his absence, allowing him to get in touch with these callers in such sequence as he may think necessary, and without the delay of listening to a program of messages.

The development of this idea led to the design of an instrument which fulfills the important requirements of simplicity, smallness, and low cost. Before describing the various features of the design in more detail, the method of operation of the new instrument will be summarized briefly. On establishing the desired connection with a terminal fitted with the apparatus, the caller will obtain a ringing tone in the usual way. After a predetermined interval of time—which would allow the called subscriber to intercept the call had he returned—a distinct signal is transmitted to the caller to indicate the presence of a number recorder at the other terminal of the line. The caller may proceed then to dial his own number, or any other number on which he desires to be called back. This number will be printed automatically on a strip of paper which issues from the number recorder. On his return the owner of the apparatus will find the record of this number, as well as that of any other calls made during his absence.

INSTALLATION

An apparatus on the principle described could be operated immediately on any private automatic telephone system, such as an internal intercommunication system in a factory or hospital, or in a railroad or police system, and so on. It is believed that recorders of this type would have definite attractions from the point of view of the telephone operating authorities, as their installation is likely to result in a considerable increase in the number of chargeable calls. Another important factor is that they would tend to reduce the time during which lines and exchange equipment are occupied by calls made to absent subscribers, obviating, in particular, repeated attempts by a caller to contact a subscriber who is absent for a prolonged period.

In its operation the number recorder relies on the transmission of transients derived from the original d-c pulses sent out by the caller's operation of the dial. These signals are received by the recorder, amplified, reshaped and regrouped, and eventually made to operate the printing mechanism. The installation of the recorder is simple and no equipment or circuit changes would be required either at the exchanges or the subscriber's terminal, other than the connection of the instrument to the line and to the existing handset.

A number of experimental models of the new instrument were evolved, and in its final form the recorder consists of a self-contained unit occupying a volume of no more than

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one-sixth of a cubic foot. With the exception of the small printing mechanism, the instrument contains standard parts, and its maintenance consists mainly of changing a spool of tape at relatively long intervals. Its power consumption during the reception of a call is approximately 30 watts, which is less than that of an ordinary electric light bulb.

OPERATION

With the line and handset connected as indicated, and the provision of a continuous power supply to the instrument, the number recorder is ready for operation. During normal telephone conversations the recorder is disconnected completely by setting a selector key, situated on the front panel of the instrument, to the "phone" position. On leaving his premises, the subscriber sets the key to "record;" then the handset is disconnected and the number recorder is ready to receive calls. No power is consumed during waiting periods. On the reception of a call, the ringing current from the exchange operates a relay in the recording instrument which switches on the power supply to an amplifying valve, allowing sufficient time for the filament to heat up, and starting up a thermal timing device. At the same time, a small pilot light on the front panel lights, indicating that a call is being received. In addition, a separate bell in the recorder is operated directly by the ringing current to call the attention of the subscriber to the fact, should he inadvertently have left the selector key in the "record" position, while he is at home. The timing device allows the bell to ring for a period of 15 seconds; at the expiration of this period, a distinct signal is transmitted to the caller for a period of five seconds.

The significance of this signal, which serves to inform the caller of the absence of the called subscriber and the existence of a number recorder, of course must be known to him. In the case of a private telephone system, the various users would be made familiar with the use of the recorder, and will dial back the number to be recorded.

The circuit comprises a further timing device which is arranged to release the line and remove the power supply of the number recorder after a period of ten seconds, if during this period no dialing pulses are received. Upon the reception of a new train of pulses, the 10-second cycle is renewed. This feature ensures that the line is occupied for a minimum time whether use be made of the facility of the number recorder, or not. A final tone signal is transmitted at the end of the last 10-second period, which is just prior to the cutting-off of the line, indicating to the caller that no further information will be recorded. This signal is of the same type as the initial signal, and is timed to last five seconds. At the same time, the paper is advanced to provide a gap between successive records, and immediately upon the removal of the power supply and release of the line, the number recorder is ready to receive a further call.

THE PRINTED RECORD

Several alternative printing processes were considered and tried experimentally. The system finally adopted is both simple in operation and maintenance. It consists of a single spool of white paper and a strip of special carbon paper interwound, both paper and carbon issuing through an opening at the side of the case, after passing the type wheel and a printing hammer. The capacity of the small spool is considerable; the total number of calls, for instance, of 7-digit numbers that can be recorded on one strip of paper before a refill spool has to be inserted is approximately 1,000. It is proposed to employ red carbon or paper for the last few inches of tape in order to call the subscriber's attention to the fact that the spool needs replacing. Care was taken in the design to make the insertion of a new spool a very simple operation, so that no special precautions have to be observed. A feeler switch could be arranged to prevent the number recorder from accepting further calls at the end of a spool, although this was not incorporated in the experimental models.

Regarding the record itself, it is in the form of numerals only. An exchange code, therefore, will appear as a number, but dialing of this number establishes, of course, the correct connection.

Resonance Radiation

How do excited atoms in a gas-filled tube behave when the power is switched off? Three scientists, working for the Westinghouse Electric Corporation, now are investigating the problem. Their findings may result in improved fluorescent lamps and electronic tubes, and possibly revolutionary new light sources.

In a fluorescent lamp, for example, their studies reveal that the electric discharge therein does not terminate the exact instant the lamp is de-energized. Actually, the billions of light-producing atoms within the lamp continue to radiate for a few millionths of a second thereafter. This short-lived "posthumous" light, which is termed resonance radiation, bounces from atom to atom of mercury until it eventually escapes. A more exact knowledge of atom behavior during this short interval may unearth new ways of adjusting the "prison term" of the radiation. New and more efficient electronic devices then might be possible.

At present, the group, comprising Dr. Theodore Holstein, Dr. Daniel Alpert, and Arthur O. McCoubrey, is measuring the short-term life of radiation by means of a high-speed device that can turn ultraviolet light on or off in less than one-millionth of a second. When the light strikes a tube filled with mercury vapor, such as a fluorescent lamp, the atoms inside the tube catch this radiation, become excited, and re-emit the same light. The apparatus measures the number of times the radiation is tossed from atom to atom before escaping from the tube.

The behavior of entrapped radiation was predicted two years ago by Dr. Holstein. His theory has been confirmed by the Westinghouse scientists' experiments. Their research also will add to the knowledge of what excited atoms are doing when the tube is in an energized state.

Digests of Papers Presented at Conferences on Textile Industry

These are authors' digests of some of the papers presented at the two special AIEE technical conferences on electrical engineering problems in the textile industry that were held in Boston, Mass., May 3, 1949; and at Georgia Institute of Technology, Atlanta, Ga., May 27–28, 1949. The papers are not scheduled for publication in AIEE Transactions, or AIEE Proceedings, nor are they available from the Institute.

Tandem Drive for Textile Printing Machines; *L. T. Jester* (*General Electric Company, Boston, Mass.*).

The continuous printing of fabrics with machines operated in tandem requires carefully co-ordinated adjustable speed drives. Electric drives offer several advantages and are generally used in preference to mechanical drives on modern range installation.

Printing machines apply colors in various designs to continuously moving fabric surfaces. The printing machine today consists of a large drum or print cylinder which carries cloth to be printed. Around its circumference are mounted 1 to 16 engraved color rolls, all rolls being driven from a drive gear. Other parts of the machine which carry gray or white goods consist of draw rolls, dry cans or air dryers, winders and folders, all of which must be driven in synchronism with the cloth as it enters or leaves the printer. Storage scrays are sometimes inserted at the entrance or exit to the machine to facilitate continuous operation.

The first drives consisted of belts and pulleys operating with a clutch and receiving power from a line shaft to drive the various units. These drives left something to be desired since they were noisy, bulky, and required excessive maintenance. Many machines actually transferred the motive power from the line shaft or single motor drive through the material to be printed, to the backing cylinder to which were attached pulleys and belts furnishing motive power for the remainder of the units. This method placed undue strain on the cloth since print rolls had to be set with sufficient pressure to prevent slippage while driving the machine. These foregoing factors led to an analysis of the drive in an attempt toward improvement.

Operating requirements such as adjustable speed, slow and stepless acceleration and deceleration, low threading speed, elimination of line shafts, belts, and pulleys, close tension control, and so forth, pointed to an adjustable-voltage Ward-Leonard type of tandem drive. A motor-operated generator-field rheostat was selected to provide gradual but fairly rapid acceleration and deceleration. "Soft" motors were used at all points except print machine and dry cans since they give reasonably constant cloth tension over the required speed range. Load-indicating ammeters were installed on the motors to enable operators to control tension more accurately.

In order to provide accurate speed control at the critical point between the printer and dry cans without contacting the cloth, a tachometer generator is attached to a drag roll at the entrance to the printer and a second attached to the dry can motor. The voltage signals from these two units are compared and inserted in an electronic circuit which controls and partially supplies the field of the dry cans motor, thereby insuring accurate speed control at the critical point.

A surface winder for the gray goods is provided since it requires no special control scheme to vary speed in order to hold tension as the roll builds up. The printed goods are folded after passing through the dry cans.

Draw roll motors at the scray entrance are provided with 50 per cent increase above basic speed to enable scray to be filled while machine is operating at high speed. Field control of 25 per cent above basic speed is provided for the remainder of the motors to permit vernier adjustment between units and to take care of change in print roll diameter occurring before print roll pinion change is necessary.

A complete set of operators controls was provided for mounting near the printer. These consisted of manually adjusted generator field rheostat for preset speed control, master control station containing *RUN-THREAD-JOG-STOP-SAFE-RUN* functions, cloth speed indicator, and draw adjusting potentiometer for dry cans. Tandem-*OFF* stations were mounted near individual motors and emergency stop push buttons actuating dynamic braking installed at strategic points.

Individual drive for each unit permits installation of simple metering equipment which can give reasonable indication of cloth tension as it progresses through the machine thus an additional means of quality control is present which cannot be easily included or adjusted in a line shaft or belt and pulley drive.

The Ratio Meter and Speed Ratio Tachometer as Applied to Textile Production; *Raymond T. Pierce* (*Weston Electrical Instrument Corporation, Newark, N. J.*).

Before we can appreciate how a speed ratio tachometer or percentage stretch indicator operates, it is necessary to understand the principle of operation of the ratio meter. In the past, a differential meter has been used and calibrated in per cent. This will be correct for one condition only where there is a fixed reference base line for one side of the differential circuit. It will not be correct, when both sides are variable.

The ratio meter resulted from a war-time requirement for measuring relative low temperatures on aircraft engines which had to be shown on a rugged panel instrument. This dictated the use of the resistance bulb method of temperature measurement, but we had to solve the problem of giving correct readings under conditions of direct voltage variations of ±20 per cent.

Ratio meters had been built but none on the permanent magnet moving coil principle which operated on current values low enough to prevent local heating in the resistance bulb.

The ratio meter that was developed was similar to the conventional permanent magnet moving coil instrument mechanism with the following exceptions:

1. There are two moving coils placed end to end, passing through a hole in the center of the core.
2. The air gaps in which the coils turn are not uniform but are identical on each side of the vertical center line. This is accomplished by moving the core out of center along the vertical center line.
3. There are no control springs.
4. The torque of one coil opposes the torque of the other.

If the current in each coil is the same, the torques balance with the coils in the horizontal position. If the current in one coil increases, the torque moves this coil into a weaker magnetic field and the other coil into a stronger magnetic field until the torques balance. The instrument, therefore, indicates the ratio between the two currents.

This mechanism has been placed in a large switchboard instrument case with a transformer and rectifier to provide an industrial remote indicating resistance bulb thermometer which is unaffected by changes in control voltage. It can be connected to any 115-volt 60-cycle circuit.

A flat fast-acting resistance bulb is provided which will measure surface temperatures of yarn in a slasher, fabrics, and the like.

This instrument provided the answer to the problem of making a percentage stretch indicator. We have had available for many years a d-c tachometer generator which produced a voltage proportional to speed. By gearing one of these to the input roll and an identical generator to the output roll, the instrument was connected to these generators to indicate the ratio of the two speeds and was calibrated in terms of per cent stretch.

This same system has been used on sanforizers to show shrinkage, on rug sizing machines to control the amount of sizing deposited, on range finishing machines to show synchronization, and on other applications where the ratio of two speeds or two electrical quantities gives useful production information.

Electronic Instrumentation as Applied to the Textile Industry; *L. E. Cuckler* (*Minneapolis Honeywell Regulator Company, Brown Instrument Division, Philadelphia, Pa.*).

During the last few years, electronics have become an important industrial tool in the textile industry, particularly in continuous processes. An example of a widely used electronic application may be found in the continuous balance potentiometer. This *ElectroniK* potentiometer is more than seven times as sensitive as the mechanical instrument and furthermore follows changes in a process as they occur rather than trying to catch up with them afterwards as the mechanical does.

The *ElectroniK* potentiometer is a very versatile instrument. It is used for the measurement and control of temperature, moisture, regain, viscosity, pH, humidity, stretch, stress, speed, and many other variables by the use of various primary sensing devices.

Of particular interest to the textile industry is the *Moist-o-Graph* which employs the d-c conductivity principle for the measurement of moisture regain in warp yarn on slashers. The magnitude of a direct current which passes through the yarn bears a definite relationship to the moisture content of the yarn. This current is measured and recorded by the *Moist-o-Graph*.

There are two common methods of regain control employed on slashers. The most frequently used is speed control by the interlocked system (where the *Moist-o-Graph* regulates the set point of the dryer temperature controller) is receiving increased attention. In the second system, the speed is set at the optimum rate for the type of yarn being slashed.

Both viscosity and pH measurements require special sensing elements. The viscosity unit is of the rotational type which measures viscosity by the torque required to rotate the measuring element. pH is measured by glass electrodes which feed their signal to a preamplifier.

Surface temperature of textile materials now can be measured by a low temperature radiation pyrometer and direct relative humidity measurements can be accomplished by means of a Dunmore element. Both of these devices are employed with an *ElectroniK* instrument.

Adaptations of strain gauges to the potentiometer permit textile stress analyses and the use of tachometer generators for measuring speed ratios allows a slightly modified instrument to record stretch between any two convenient points.

Electronics are also employed in flame failure safety devices either by photoelectric cells or devices which utilize flame rectification. Such devices shut off the fuel supply automatically whenever the flame fails.

Another interesting application of electronics in instruments used by the textile and other industries is in electrically operated controllers. The electronic principle increases control sensitivity and greatly decreases the mechanical power needed to actuate the control mechanism.

Minimum Requirements for Safe Electrical Installations in Cotton Mills; *C. F. Hedlund* (*Associated Factory Mutual Fire Insurance Companies, Boston, Mass.*).

Fires occur more frequently in textile plants than in any other class of industry insured by the Associated Factory Mutual Fire Insurance Companies. Many of these fires are due to causes which are preventable, among which electricity is foremost.

Some of the rules of the present National Electrical Code pertaining to electrical installations in cotton mills are considered by many to be impractical, because the equipment that is now required where cotton fibres are present in appreciable amounts is too costly. The NEMA (National Electrical Manufacturer's Association) Type *9* enclosure which is required for control and protective equipment in linty areas is very expensive in comparison with the general purpose enclosure, consequently the latter is generally used and experience shows it is not suitable for most of the conditions. Obviously an enclosure is needed that will have some of the characteristics of the NEMA Type *9* enclosure, but it should not be much more expensive than the general purpose enclosure. It should be rugged enough to withstand the abuse that it is likely to receive and tight enough to prevent the infiltration of lint. The NEMA Type *1-A* semi-dust-tight enclosure is not much more expensive than the general purpose enclosure and it is of suitable design for most of the lint conditions but unfortunately it is not now commercially available for all types and sizes of switches and motor controllers used in linty areas.

The minimum requirements for safe electrical installations call for rigid metal conduit in heavy lint areas, such as in opener and picker rooms, card and dust rooms, cotton bins, lap storage areas, and so forth. Electric metallic tubing is permitted in other occupancies of moderate or light lint accumulations and the installation of wiring of any kind is discouraged in low, unsprinklered combustible basement areas.

Where there is considerable vibration, such as around looms, Type *SO* multiconductor flexible cord is advised with special water-tight connectors for the wiring between the controller and the motor.

Bus ducts should not be installed in opener and picker rooms, or in areas where lint is likely to accumulate inside the bus duct.

In linty areas motors of the totally enclosed type are preferred. For sizes larger than 15 horsepower, special textile type or enclosed pipe ventilated type are advised. Totally enclosed fan cooled motors are not recommended for use in linty areas. Open frame nonsparking induction motors are acceptable where lint accumulations are slight.

Enclosures for motor controllers, switches, fuses and circuit breakers, and similar spark producing equipment when installed in areas of moderate lint accumulations should be of the NEMA Type *1-A* semi-dust-tight type, or the equivalent. In heavy lint areas as in dust rooms, enclosures should be NEMA Type *5* or better.

Cord pendent lights should not be installed. Pipe pendent lighting fixtures and ceiling units are preferred. Fluorescent lights should have tight enclosures for the ballasts and in areas where the lint accumulations are severe should be equipped with glass covers. The reset type of starter should be used generally. Exposed incandescent lights should be provided with heavy glass globes where cotton lint and flyings are present and in cotton bins enclosed in dustproof fixtures, approved for Class II Group *G* locations.

Electric cranes and hoists supplied from bare overhead trolley conductors are permitted in cotton storage areas with special safeguards.

Ventilated dry type transformers are not permitted for use in any area where there are combustible lint and flyings present.

Stroboscope Analysis of Its Modern Automatic High-Speed Bobbin-Changing Dobby Loom; (*An industrial film, Crompton and Knowles Loom Works, Worcester, Mass.*).

The film represents the initial effort of Crompton and Knowles Loom Works with respect to education of mill personnel concerning the operation and function of various mechanical and electro-mechanical mechanisms of the *S-6* Automotic Bobbin-Changing Dobby Loom. It shows the action of various mechanisms that perform their operational cycles in but a fractional part of a second.

The particular type of automatic bobbin-changing dobby loom filmed (designated as *S-6*) was designed to meet the demands of the silk, rayon, acetate, and nylon trade.

Electric Power Applications in the Textile Industry

Copies of this publication, sponsored by the AIEE Committee on Industrial Power Applications, still are available. A consolidated reprint of four papers, this booklet covers certain aspects of the modern use of electric power in the textile industry such as electrification of the industry, power distribution, electric equipment, and electric drives.

Orders together with remittances of \$0.80 per copy (\$0.40 to AIEE members) should be sent to the AIEE Order Department, 33 West 39th Street, New York 18, N. Y.

The new 16-millimeter black-and-white 31-minute sound film opens with a full view of the *S-6* loom in operation. Then each major motion of the loom is covered. Construction and method of operation are shown and described.

Some excellent slow-motion sequences slow down such rapid operations as bobbin transfer, shuttle boxing, and so forth, so that the actual happenings may be observed in detail. The film describes and shows the operation of:

dobby, let-off, shuttle inserting filling in shed, bobbin magazine (two-cell), electric filling feeler, box motion, bobbin transfer, filling cutter, filling end remover, vacuum thread collector, center filling-stop motion, electric warp-stop motion, crankshaft connections at time of protection, bat-wing pick motion, operation of pickers at both ends of lay, parallel motion, and floating shuttle binder.

The 16-millimeter high-speed stroboscopic camera used in filming the slow-motion scenes was manufactured by Crompton and Knowles Loom Works. The speed range is from 240 to 1,200 frames per second. When operating at the maximum speed, 100 feet of film are exposed in approximately $3^1/_3$ seconds. When projected at the standard sound-film rate of 24 frames per second, the 100 feet of film shot at 1,200 frames per second will take approximately three minutes to view, or, in other words, 50 times slower than the action actually occurred. The slow-motion sequences of this film were shot at 480 frames per second, or a 20 to 1 reduction, a speed amply fast to permit study of any motion of the loom. The duration of flash is about six to eight microseconds, and the effective photographic exposure time is from two to four microseconds.

The camera is of the shutterless type—the shutter effect being derived from stroboscopic flash lamps which are controlled by a commutator attached to the film drive sprocket shaft, thereby synchronizing each individual frame with a flash of the stroboscopic lamp. In other words, when shooting at the rate of 480 frames per second, each stroboscopic lamp flashes 480 times per second—one flash for each frame that passes the aperture of the camera. Therefore, the extreme sharpness of each individual frame readily adapts the filmed sequence to frame by frame analysis as used in engineering studies. The 220-volt alternating-current input to the power pack is converted and applied to the stroboscopic flash lamp at 2,000–2,400 direct volts. The power pack has a 15-kw capacity, and can carry momentary loads up to 30 kw.

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Aeronautical Electrical Equipment Standardization

W. V. Boughton, liaison representative with NASC and SAE	South Pasadena, Calif.

Alfred Noble Prize Committee, ASCE

T. M. Linville	Schenectady, N. Y.

American Association for the Advancement of Science, Council

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Engineering Foundation Board

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Engineering Societies Monographs Committee

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Engineers' Council for Professional Development

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General Electric Educational Fund Fellowship Committee

J. F. Fairman	New York, N. Y.

Hertz Award Committee

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Hoover Medal Board of Award

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John Fritz Medal Board of Award

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B. D. Hull	Dallas, Tex.
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Joint Committee for Development of Statistical Applications in Engineering and Manufacturing

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George Sutherland	New York, N. Y.
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Marston Medal Board of Award

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National Association of Corrosion Engineers, Inter-Society Committee on Corrosion

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Robin Beach	Brooklyn, N. Y.
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Washington Award Commission

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Frank V. Smith	Chicago, Ill.

World Power Conference, Executive Committee of United States National Committee

J. F. Fairman	New York, N. Y.

Sections

Name	District	When Organized	Chairman	Secretary	Secretary's Address
Akron	2	Aug. 12, '20	H. P. Davis	J. R. Dorsey	YMCA, Akron 8, Ohio
Alabama	4	May 22, '29	J. W. Davis	Gayle Riley	Alabama Power Co., 600 No. 18th St., Birmingham 2, Ala.
Arizona	8	Mar. 22, '41	W B Bustard	I. G. Jenkins, Jr	Central Arizona Light & Power Co., 2215 No. 25th St., Phoenix Ariz.
Arkansas	7	Apr. 23, '47	W. A. Lewis, Jr.	R. B. Newman	Reynolds Metals Co., Jones Mills Plant, Jones Mills, Ark.
Arrowhead	5	Apr. 23, '47	P. A. Beckjord	Roy B. Wiprud	137 Greenwood Lane, Duluth 3, Minn.
Beaumont	7	June 27, '45	R. W. Parker	A. F. Briggs	Sun Oil Co., Beaumont, Tex.
Boston	1	Feb. 13, '03	J. J. Loustaunau	H. J. Randolph	J. J. Costello Co., 131 Clarendon St., Boston, Mass.
Canton	2	Nov. 5, '47	C. L. Lucal	R. V. Kelch	4520 13th St., N. W., Canton 7, Ohio
Central Indiana	5	Jan. 12, '12	G. M. Grabbe	J. W. Sears	Indiana Bell Tel. Co., 240 No. Meridian St., Indianapolis 9, Ind.
Chicago	5	1893	H. E. Nason	E. L. Michelson	Commonwealth Edison Co., 72 West Adams St., Chicago, Ill.
Cincinnati	2	June 30, '20	F. E. Wiatt	D. T. Michael	Cincinnati Gas & Elec. Co., 4th & Main Sts., Cincinnati 2, Ohio
Cleveland	2	Sept. 27, '07	R. L. Oetting	J. A. Cortelli	Clark Controller Co., 1146 East 152nd St., Cleveland 10, Ohio
Columbus	2	Mar. 17, '22	N. L. Greene	C. E. Warren	Ohio State Univ., Columbus 10, Ohio
Connecticut	1	Apr. 16, '21	J. B. Powell	F. W. Buck	United Illuminating Co., 80 Temple St., New Haven 6, Conn.
Dayton	2	June 9, '43	E. Herzog	J. G. Tolentino	2 Palermo Place, Dayton 4, Ohio
Denver	6	May 18, '15	F. A. Eastom	E. R. Jones	Mountain States Tel. & Tel. Co., Box 960, Denver 1, Colo.
East Tennessee	4	Sept. 2, '36	T. D. Talmage	J. D. Sharp, Jr.	3004 Pope Drive, Chattanooga, Tenn.
Erie	2	Jan. 11, '18	M. J. Kolhoff	J. F. Davis	General Elec. Co., 2901 East Lake Road, Erie, Pa.
Florida	4	Jan. 28, '31	R. S. Davis	Jess D. Thomas	904 Ethan Allen, Jacksonville, Fla.
Fort Wayne	5	Aug. 14, '08	J. F. Eitman	J. H. Capps	General Elec. Co., 1635 Bway, Fort Wayne, Ind.
Georgia	4	Jan. 14, '04	E. S. Lammers	H. P. Peters	Georgia Inst. of Tech., Engg. Experiment Sta. Atlanta, 3 Ga.
Houston	7	Aug. 7, '28	W. O. Ray	W. E. Silvus	P. O. Box 2537, Houston, Tex.
Illinois Valley	5	June 30, '45	E. W. Stone	E. Krefting	317 Persimmon St., Peoria 6, Ill.
Iowa	5	June 29, '29	T. W. Schroeder	F. E. Keith	Keith Elec. Construction Co., 1213 Walnut St., Des Moines 9, Iowa
Ithaca	1	Oct. 15, '02	H. L. Livingood	S. W. Zimmerman	102 Valley Road, Ithaca, N. Y.
Kansas City	7	Apr. 14, '16	R. M. Kerchner	A. J. Nicholson	Kansas City Power & Light Co., P.O. Box 679, Kansas City 10, Mo.
Lehigh Valley	2	Apr. 16, '21	C. H. Sprague	A. L. Price	Pennsylvania Power & Light Co., Hazleton, Pa.
Los Angeles	8	May 19, '08	E. L. Bettannier	E. K. Sadler	Kelman Elec. & Mfg. Co., 1650 Naud St., Los Angeles 12, Calif.
Louisville	4	Oct. 15, '26	R. D. Spalding	H. T. Smith	2816 Virginia Ave., Louisville 11, Ky.
Lynn	1	Aug. 22, '11	R. S. Schlotterbeck	A. M. Bjontegard	General Elec. Co., 920 Western Ave., West Lynn, Mass.
Madison	5	Jan. 8, '09	Leonard Hesse	Rubin A. Imm	102 Electrical Lab., Univ. of Wis., Madison, Wis.
Mansfield	2	Mar. 6, '39	E. C. Ryan	F. L. Hanson	The Ideal Elec. & Mfg. Co., Mansfield, Ohio
Maryland	2	Dec. 16, '04	F. H. Rogers	J. W. Magee	Westinghouse Elec. Corp., Std. Oil Bldg., Baltimore 3, Md.
Memphis	4	May 22, '30	W. B. Thompson	J. R. Owens	3563 Mimosa St., Memphis, Tenn.
Mexico	7	June 29, '22	E. D. Luque	F. Aubert	Apartado Postal 1399, Mexico,Federal District, Mexico
Miami	4	Feb. 3, '49	C. H. Summers	W. T. Edwards, Jr.	Southern Bell Tel. & Tel. Co., 1410—20th St., Miami Beach, Fla.
Michigan	5	Jan. 13, '11	E. F. Dissmeyer	O. E. Bowlus	18628 Lauder, Detroit 19, Mich.
Milwaukee	5	Feb. 11, '10	F. J. Van Zeeland	C. P. Feldhausen	Cutler-Hammer, Inc., 315 No. 12th St., Milwaukee 2, Wis.
Minnesota	5	Apr. 7, '02	Lincoln Rietow	R. E. Willey	Northwestern Bell Tel. Co., 224 So. 5th St., Minneapolis 2, Minn.
Montana	9	June 24, '31	J. R. Walker	Marion O. Hansen	112—14th St., Great Falls, Mont.
Montreal	10	Apr. 16, '43	N. L. Morgan	A. Malkin	Canadian Car & Foundry Co. Ltd., 621 Craig St. W., Montreal, Quebec 3, Canada
Nebraska	6	Jan. 21, '25	F. C. Howard	C. N. Allen	Allis-Chalmers Mfg. Co., 9th & Farnam Sts., Omaha 8, Nebr.
New Mexico-West Texas	7	Mar. 7, '40	Oscar Gutsch	G. R. Yelderman	General Elec. Co., 109 North Oregon, El Paso, Tex.
New Orleans	4	Dec. 8, '33	E. I. Blanchard	H. E. Pritchard, Jr.	5836 General Haig St., New Orleans 19, La.
New York	3	Dec. 10, '19	D. W. Taylor	J. P. Neubauer	402 Fairway Road, Ridgewood, N. J.
Niagara Frontier	1	Feb. 10, '25	F. C. Rushing	C. J. Brumbaugh	129 Hunt Ave., Hamburg, N. Y.
Niagara International	10	Aug. 5, '48	W. G. A. Barr	E. A. Dillon	11 York St., St. Catharines, Ontario, Canada
North Carolina	4	Mar. 21, '29	G. G. Mattison	B. V. Martin	Westinghouse Elec. Corp., 210 East Sixth St., Charlotte 1, N. C.
North Texas	7	May 18, '28	P. G. Wallace	A. L. Jones, Jr.	General Elec. Co., 1801 North Lamar St., Dallas, Tex.
Oklahoma City	7	Feb. 16, '22	E. W. Allen	J. C. Turner	Southwestern Bell Tel. Co., 1004 Telephone Bldg., Oklahoma City 2, Okla.
Ottawa	10	June 23, '49	Fred Fleming	Gordon Cathcart	137 Clarendon Ave., Ottawa, Ontario, Canada
Panhandle Plains	7	June 12, '47	George Dupree	G. R. Bunton	Box 631, Lubbock, Tex.
Philadelphia	2	Feb. 18, '03	W. F. Henn	H. H. Sheppard	Rumsey Elec. Co., 1007 Arch St., Philadelphia 7, Pa.
Pittsburgh	2	Oct. 13, '02	F. H. Schlough	L. N. Grier	Aluminum Co. of America, 801 Gulf Bldg., Pittsburgh, Pa.
Pittsfield	1	Mar. 25, '04	T. E. Rodhouse	G. L. Vallin	General Elec. Co., Pittsfield, Mass.
Portland	9	May 18, '09	R. B. Temple	Waldo Porter	Aluminum Co. of America, Vancouver, Wash.
Providence	1	Mar. 12, '20	O. E. Sawyer	C. B. Leathers	General Elec. Co., 111 Westminster St., Providence, R. I.
Richland	9	Apr. 23, '48	W. J. Dowis	R. B. Crow	206 Barth Ave., Richland, Wash.
Rochester	1	Oct. 9, '14	J. H. Rogers	E. M. Morecock	817 Chili Ave., Rochester, N. Y.
Rock River Valley	5	Apr. 23, '47	S. A. Coxhead	W. C. Busch	1421 North Church St., Rockford, Ill.
St. Louis	7	Jan. 14, '03	R. C. Horn	J. C. Lebens, Jr.	7322 Melrose Ave., University City, Mo.
San Diego	8	Jan. 18, '39	J. F. Sinnott	O. L. Doolittle	4738 Works Place, San Diego 4, Calif.
San Francisco	8	Dec. 23, '04	T. C. McFarland	Remi Bollaert	Westinghouse Elec. Corp., 410 Bush St., San Francisco 8, Calif.
Schenectady	1	Jan. 26, '03	J. C. Page	L. T. Rader	General Elec. Co., Bldg. 69, Schenectady 5, N. Y.
Seattle	9	Jan. 19, '04	Ray Rader	H. R. Loew	General Elec. Co., 710 Second Ave., Seattle 11, Wash.
Sharon	2	Dec. 11, '25	G. R. Monroe	A. J. Maslin	59 South Oakland Ave., Sharon, Pa.
Shreveport	4	June 12, '47	L. T. Williams	C. M. L. Pons	3536 Del Rio, Shreveport 65, La.
South Bend	5	Feb. 26, '41	R. A. Cliff	Rayhue Neighbours	526 So. Twyckenham Drive., South Bend 15, Ind.
South Carolina	4	Mar. 2, '40	E. P. Miller	W. E. Dent, Jr.	The Springs Cotton Mills, Lancaster, S. C.
South Texas	7	May 23, '30	L. L. Antes	R. R. Krezdorn	153 Engg. Bldg., University of Texas, Austin, Tex.
Spokane	9	Feb. 14, '13	T. W. MacLean	R. M. Gilbert	Westinghouse Elec. Corp., 1023 West Riverside Ave., Spokane 8, Wash.
Springfield	1	June 29, '22	W. E. Maxwell	W. L. Vest, Jr.	54 Churchill Road, West Springfield, Mass.
Syracuse	1	Aug. 12, '20	J. D. Hershey	H. H. Graley	Central New York Power Corp., 300 Erie Blv'd., W. Syracuse, N. Y.
Toledo	2	June 3, '07	F. A. Furfari	W. M. Campbell	2145 Central Grove Ave., Toledo, Ohio
Toronto	10	Sept. 30, '03	J. M. Somerville	W. R. Harmer	Hydro-Elec. Power Co. of Ont., 620 Univ. Ave., Toronto, Ontario, Canada
Tulsa	7	Oct. 1, '37	Dick Ray	W. H. Plumer	Southwestern Bell Tel. Co., 424 So. Detroit, Tulsa, Okla.
Urbana	5	Nov. 25, '02	H. N. Hayward	P. R. Egbert	University of Illinois, Urbana, Ill.
Utah	9	Mar. 9, '17	F. O. Wald	J. A. McDonald	General Elec. Co., P. O. Box 779, Salt Lake City 1, Utah
Vancouver	10	Aug. 22, '11	W. J. Lind	F. O. Wollaston	B. C. Elec. Ry. Co., Ltd., 425 Carroll St., Vancouver, British Columbia, Canada
Virginia	4	May 19, '22	L. Saunders	P. R. Spracher	P. O. Box 1194, Richmond 19, Va.
Washington	2	Apr. 9, '03	Dixon Lewis	L. V. Berkner	7213 Bradley Blvd., Bethesda 14, Md.
West Virginia	2	Apr. 9, '40	E. B. Ellerbe	J. J. Fitzgibbon	306 McCorkle Ave., Charleston 28, W. Va.
Western Virginia	4	June 23, '49	Ira H. McMann	E. L. Munday, Jr.	P. O. Box 2021, Appalachian Elec. Power Co., Roanoke, Va.
Wichita	7	Sept. 16, '37	R. F. Dice	J. E. McNicol	Kansas Gas & Elec. Co., 201 No. Market, Wichita 2, Kans.
Worcester	1	Feb. 18, '20	D. R. Percival	W. G. Coleman	General Elec. Co., 507 Main St., Worcester 8, Mass.
Total Sections	85				

Subsections

Name	Chairman	Secretary	Secretary's Address
Albuquerque (New Mexico-West Texas Section)	W. O. McCord, Jr.	A. D. Taylor	1722 East Gold Ave., Albuquerque, N. Mex.
Baton Rouge (New Orleans Section)	F. R. Adams	E. F. Tims	3155 Lakeshore Drive, Baton Rouge 15, La.
Billings (Montana Section)		Harold Black	714 Avenue G, Billings, Mont.
Binghamton Area (Ithaca Section)	K. S. Koon	J. P. Peterson	Westinghouse Elec. Corp., 86 Court St., Binghamton 62, N. Y.
Boulder City (Los Angeles Section)	W. H. Taylor	F. A. Latham	Los Angeles Water & Power Dept., 600 Nevada Highway, Boulder City, Nev.
Casper, Wyo. (Denver Section)			
Central Texas (North Texas)			
Centre County (Pittsburgh Section)	R. J. E. Hemman	R. M. Smith	Ord. Res. Lab., Penna. State Col., State College, Pa.
Charleston (South Carolina Section)			
Charlotte (North Carolina Section)	M. F. Leftwich	I. G. Wallace, Jr.	205 Wales Ave., Charlotte, N. C.
Columbia (South Carolina Section)			
Corpus Christi (South Texas Section)	A. B. Weaver	J. H. Watts, Jr.	Westinghouse Elec. Corp., 508 Medical Professional Bldg., Corpus Christi, Tex.
Fort Worth (North Texas Section)	J. L. Candry	Karl J. Ratliff	1101 Electric Bldg., Fort Worth 2, Tex.
Fox River Valley (Milwaukee Section)	Herbert F. Weckwerth	Donald Christison	209 Frederick St., Menasha, Wis.
Freeport (Houston Section)	H. K. Brown	R. B. Adams	P. O. Box 413, Lake Jackson, Tex.
Fresno (San Francisco Section)	C. L. Smith	William Green	U. S. Bureau of Reclamation, T. W. Patterson Bldg., Fresno 1, Calif.
Great Falls (Montana Section)			
Hamilton (Toronto Section)			
Hampton Roads (Virginia Section)	C. E. Hastings	S. H. Fletcher	Va. Electric & Power Co., Newport News, Va.
Hudson Valley (New York Section)	W. E. Smalley	J. E. Ruscher	49 Carroll St., Poughkeepsie, N. Y.
Jackson (Miss.) (New Orleans Section)			
Jacksonville (Florida Section)			
Johnstown (Pittsburgh Section)	W. R. Wood	R. S. Baum	Univ. of Pittsburgh, 325 Cypress Ave., Johnstown, Pa.
Lake Charles (New Orleans Section)	G. B. S. Ricketts	J. J. Alleman	29 Hibiscus Road, Maplewood, La.
Lancaster York (Maryland Section)	W. H. Freund	H. H. Wittenberg	RCA Victor Div., Radio Corp. of America, Lancaster, Pa.
Lima (Dayton Section)	B. O. Austin	O. M. Swain	Westinghouse Elec. Corp., Engg. Dept., Lima, Ohio
Mid-State (North Carolina Section)	F. R. Jackson, Jr.	L. H. Allcorn, Jr.	2425 Elizabeth Ave., Winston-Salem 7, N. C.
Muscle Shoals (East Tennessee Section)			
Nashville (Memphis Section)	Walter Criley	E. R. Boruch	1229 Stahlman Bldg., 234—3rd Ave., North, Nashville 3, Tenn.
New Hampshire (Boston Section)			
New Jersey (New York Section)			
Northern New York (Syracuse Section)	J. B. Pitman	L. F. Pries	New York State Agric. & Tech. Inst., 8 College St., Canton, N. Y.
Northwest Arkansas (Arkansas Section)	W. B. Stelzner	R. E. Anderson	Southwestern Gas & Elec. Co., De Queen, Ark.
Oak Ridge (East Tennessee Section)			
Quad-Cities (Iowa Section)			
Red River Valley (Minnesota Section)	M. R. Hughes	H. K. Ugelstad	Northern States Power Co., 612 N. P. Ave., Fargo, N. Dak.
Richmond (Virginia Section)	C. L. Gilkeson	L. D. Johnson, 3rd	R. F. D. 7, Box 201, Richmond, Va.
Sacramento (San Francisco Section)	C. R. Day	G. A. Fleming	3711 17th St., Sacramento 18, Calif.
Saginaw Valley (Michigan Section)	E. L. Holmgren	F. H. Justin	401 W. Sugnet Road, Midland, Mich.
St. Maurice Valley (Montreal Section)			
San Jose (San Francisco Section)	L. O. Templeton	Warren Raab	1188 Thornton Way., Campbell, Calif.
Sangamon (Illinois Valley Section)	G. E. Sangster	J. T. Youngblood	Sangamo Elec. Co., Springfield, Ill.
Shasta (San Francisco Section)	W. G. Whitney	G. A. Thompson	U. S. Bureau of Reclamation, Redding, Calif.
Tri-State (West Virginia Section)			
West Central Texas (North Texas Section)	R. D. Henley	C. B. Herbert	Route 2, Hamlin, Tex.
West Coast (Florida)			
West Michigan (Michigan Section)	R. M. Chermak	L. A. Zahorsky	127 Colfax, N.E., Grand Rapids, Mich.
Wilmington (Philadelphia Section)	E. W. Randall, Jr.	E. R. Streed	R. F. D. 3, Box 156, Wilmington, Del.
Zanesville (Columbus Section)	R. W. Hartsook	C. G. Winters	1115 Seborn Ave., Zanesville, Ohio

Geographical District Executive Committees

District	Chairman (Vice-President, AIEE)	Secretary (District Secretary)	Chairman, District Committee on Student Activities
1 North Eastern	Victor Siegfried, American Steel & Wire Co., Worcester 7, Mass.	Frederick G. Webber, 9 Federal Court, Springfield 5, Mass.	A. G. Conrad, Yale University, New Haven, Conn.
2 Middle Eastern	C. G. Veinott, Westinghouse Electric Corp., Lima, Ohio	W. A. Dynes, 312 Lonsdale Ave., Dayton 9, Ohio	K. F. Sibila, University of Akron, Akron 4, Ohio
3 New York City	J. L. Callahan, R. C. A. Laboratories, Radio Corporation of America, 66 Broad St., New York 4, N. Y.	R. T. Oldfield, Public Service Commission, 233 Broadway, New York 7, N. Y.	F. A. Wahlers, Polytechnic Inst. of Brooklyn, 99 Livingston St., Brooklyn 2, N. Y.
4 Southern	W. J. Seeley, Duke University, Durham, N. C.	T. H. Mawson, Commonwealth & Southern Corp., 600 North 18th St., Birmingham 2, Ala.	L. V. McLean, Louisiana State University, Baton Rouge 3, La.
5 Great Lakes	E. W. Seeger, Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.	N. C. Pearcy, Pioneer Service & Engineering Co., 231 S. LaSalle St., Chicago 4, Ill.	E. W. Kane, Marquette Univ., 1515 W. Wisconsin Ave., Milwaukee 3, Wis.
6 North Central	W. C. DuVall, University of Colorado, Boulder, Colo.	G. E. Gless, Jr., University of Colorado, Boulder, Colo.	C. H. Chinburg, Colorado A. & M. College, Fort Collins, Colo.
7 South West	G. N. Pingree, General Electric Co., 1801 N. Lamar St., Dallas 2, Tex.	Gibbs A. Dyer, Southwestern Bell Telephone Co., Dallas 1, Tex.	Ralph W. Tapy, University of New Mexico, Albuquerque, N. Mex.
8 Pacific	R. A. Hopkins, Westinghouse Electric Corp., 600 St. Paul Ave., Los Angeles 14, Calif.	T. M. Blakeslee, Dept. of Water & Power, City of Los Angeles, 207 South Broadway, Los Angeles 12, Calif.	R. C. Lewis, University of Southern Calif., Los Angeles 7, Calif.
9 North West	Richard McKay, Washington Water Power Co., West 825 Trent Ave., Spokane 6, Wash.	H. C. Glaze, Jr., General Electric Co., S. 162 Post St., Spokane 8, Wash.	V. L. Palmer, University of Washington, Seattle 5, Wash.
10 Canada	A. H. Frampton, English Elec. Co. of Canada Ltd., St. Catharines, Ontario, Canada	J. I. Gram, Hydro-Electric Power Comm. of Ont., Box 237, Niagara Falls, Ontario, Canada	W. B. Coulthard, University of British Columbia, Vancouver, British Columbia, Canada

NOTE: Each District executive committee includes also the chairmen and secretaries of all Sections within the District, the District vice-chairman of the AIEE membership committee, and a member of the Sections Committee who is resident in the District.

Student Branches

Name and Location	District	Counselor (Member of Faculty)
Akron, University of, Akron, Ohio	2	K. F. Sibila
Alabama Polytechnic Inst., Auburn	4	R. D. Spann
Alabama, University of, University	4	W. F. Gray
Alberta, University of, Edmonton, Canada	10	R. E. Phillips
Arizona, University of, Tucson	8	J. C. Clark
Arkansas, Univ. of, Fayettesville	7	N. H. Barnette
British Columbia, Univ. of, Vancouver, Canada	10	W. B. Coulthard
Brooklyn, Polytechnic Inst. of, Brooklyn, N. Y., (Day)	3	F. A. Wahlers
Brooklyn, Polytechnic Inst. of, Brooklyn, N. Y., (Evening)	3	Anthony B. Giordano
Brown University, Providence, R. I.	1	F. N. Tompkins
Bucknell University, Lewisburg, Pa.	2	Ralph C. Walker
California Inst. of Technology, Pasadena	8	William H. Pickering
California, University of, Berkeley	8	R. M. Saunders
Carnegie Inst. of Technology, Pittsburgh, Pa.	2	George M. Anderson
Case Inst. of Technology, Cleveland, Ohio	2	Carl F. Schuneman
Catholic University of America, Washington, D. C.	2	J. C. Michalowicz
Cincinnati, Univ. of, Cincinnati, Ohio	2	A. C. Herweh
Clarkson College of Technology, Potsdam, N. Y.	1	George W. Reed
Clemson A. & M. College, Clemson, S. C.	4	F. T. Tingley
Colorado A. & M. College, Fort Collins	6	C. H. Chinburg
Colorado, University of, Boulder	6	W. G. Worcester
Columbia University, New York, N. Y.	3	W. A. LaPierre
Connecticut, Univ. of, Storrs	1	Clarence W. Schultz
Cooper Union, New York, N. Y.	3	E. W. Starr
Cornell University, Ithaca, N. Y.	1	M. S. McIllroy
Delaware, University of, Newark	2	H. S. Bueche
Denver, University of, Denver, Colo.	6	A. M. Stiles
Detroit, University of, Detroit, Mich.	5	H. O. Warner
Drexel Inst. of Technology, Philadelphia, Pa.	2	F. C. Powell
Duke University, Durham, N. C.	4	Otto Meier, Jr.
Fenn College, Cleveland, Ohio	2	R. W. Schindler
Florida, University of, Gainesville	4	Paul H. Nelson
George Washington Univ., Washington, D. C.	2	Jerome S. Antel, Jr.
Georgia Inst. of Technology, Atlanta, Ga.	4	H. B. Duling
Harvard University, Cambridge, Mass.	1	John C. Fisher
Idaho, University of, Moscow	9	J. Hugo Johnson
Illinois Inst. of Technology, Chicago	5	E. T. B. Gross
Illinois, University of, Urbana	5	E. A. Reid
Iowa State College, Ames	5	G. Richardson
Iowa, University of, Iowa City	5	E. B. Kurtz
Johns Hopkins University, Baltimore, Md.	2	T. Larsen
Kansas State College, Manhattan	7	Earl L. Sitz
Kansas, University of, Lawrence	7	E. B. Phillips
Kentucky, University of, Lexington	4	H. Alex Romanowitz
Lafayette College, Easton, Pa.	2	J. G. Reifsnyder
Lehigh University, Bethlehem, Pa.	2	W. Lyle Donaldson
Louisiana Polytechnic Inst., Ruston, La.	4	Milton R. Johnson, Jr.
Louisiana State University, Baton Rouge	4	L. V. McLean
Louisville, University of, Louisville, Ky.	4	Harry T. Smith
Maine, University of, Orono	1	P. M. Seal
Manhattan College, New York, N. Y.	3	Robert T. Weil
Marquette University, Milwaukee, Wis.	5	E. W. Kane
Maryland, University of, College Park	2	L. J. Hodgins
Massachusetts Inst. of Technology, Cambridge	1	E. W. Boehne
Michigan College of Mining & Technology, Houghton	5	G. W. Swenson
Michigan State College, East Lansing	5	C. E. Goodell
Michigan, University of, Ann Arbor	5	John J. Carey
Milwaukee School of Engineering, Milwaukee, Wis.	5	R. J. Ungrodt
Minnesota, University of, Minneapolis	5	J. H. Kuhlmann
Mississippi State College, State College	4	Paul B. Jacobs, Jr.
Missouri School of Mines & Metallurgy, Rolla	7	I. H. Lovett
Missouri, University of, Columbia	7	G. V. Lago
Montana State College, Bozeman	9	G. D. Sheckels
Nebraska, University of, Lincoln	6	E. J. Ballard, Jr.
Nevada, University of, Reno	8	I. J. Sandorf
Newark College of Engineering, Newark, N. J.	3	C. R. Moore
New Hampshire, University of, Durham, N. H.	1	A. J. Merlini
New Mexico College of A. & M. Arts, State College	7	Russell Riese
New Mexico, University of, Albuquerque	7	J. Lawton Ellis
New York, College of the City of, New York, N. Y.	3	Harry Baum
New York, University of, New York	3	James Ley
North Carolina State College, Raleigh	4	W. D. Stevenson, Jr.
North Dakota Agri. College, Fargo	5	Harry S. Dixon
North Dakota, University of, Grand Forks	5	K. B. MacKichan
Northeastern University, Boston, Mass.	1	Roland G. Porter
Northwestern University, Evanston, Ill.	5	A. H. Wing
Norwich University, Northfield, Vt.	1	
Notre Dame, University of, Notre Dame, Ind.	5	L. F. Stauder
Ohio Northern University, Ada	2	W. R. Ankrom
Ohio State University, Columbus	2	Edmund D. Ayres
Ohio University, Athens	2	D. B. Green
Oklahoma A. & M. College, Stillwater	7	David L. Johnson
Oklahoma, University of, Norman	7	Gerald Tuma
Oregon State College, Corvallis	9	Melvin J. Kofoid
Pennsylvania State College, State College	2	A. P. Powell
Pennsylvania, University of, Philadelphia	2	Kenneth C. Fegley
Pittsburgh, University of, Pittsburgh, Pa.	2	R. C. Gorham
Pratt Institute, Brooklyn, N. Y.	3	Robert B. Morgan
Princeton University, Princeton, N. J.	2	Norman W. Mather
Puerto Rico, University of, Mayaguez, P. R.	3	Miguel Wiewall, Jr.
Purdue University, Lafayette, Ind.	5	C. R. Nichols
Rensselaer Polytechnic Institute, Troy, N. Y.	1	Emerson D. Broadwell
Rhode Island State College, Kingston	1	John L. Hummer
Rice Institute, Houston, Tex.	7	J. S. Waters
Rose Polytechnic Institute, Terre Haute, Ind.	5	C. C. Knipmeyer
Rutgers University, New Brunswick, N. J.	3	P. H. Daggett
Santa Clara, Univ. of, Santa Clara, Calif.	8	Henry P. Nettesheim
South Carolina, Univ. of, Columbia	4	S. A. Ferguson
South Dakota School of Mines & Tech., Rapid City	6	J. O. Kammerman
South Dakota State College, Brookings	5	Wm. H. Gamble
Southern California, Univ. of, Los Angeles	8	Rodney C. Lewis
Southern Methodist Univ., Dallas, Tex.	7	F. W. Tatum
Stanford University, Stanford, University, Calif.	8	W. G. Hoover
Stevens Inst. of Technology, Hoboken, N. J.	3	W. L. Sullivan
Swarthmore College, Swarthmore, Pa.	2	C. A. Lister
Syracuse University, Syracuse, N. Y.	1	Henry F. Cooke
Tennessee, University of, Knoxville	4	W. O. Leffell
Texas, A. & M. College of, College Station	7	N. F. Rode
Texas Technological College, Lubbock	7	
Texas, University of, Austin	7	A. J. McCrocklin, Jr.
Toronto, University of, Toronto, Ontario, Canada	10	L. S. Lauchland
Tufts College, Medford, Mass.	1	A. H. Howell
Tulane University, New Orleans, La.	4	Marion E. Forsman
Union College, Schenectady, N. Y.	1	Owen G. Owens
Utah, University of, Salt Lake City	9	O. C. Haycock
Vanderbilt University, Nashville, Tenn.	4	S. R. Schealer
Vermont, University of, Burlington	1	Howard M. Smith, Jr.
Villanova College, Villanova, Pa.	2	John B. Clothier
Virginia Military Institute, Lexington	4	J. S. Jamison
Virginia Polytechnic Institute, Blacksburg	4	Claudius Lee
Virginia, University of, Charlottesville	4	Gordon Carter
Washington, State College of, Pullman	9	O. E. Osburn
Washington, University of, Seattle	9	H. M. Rustebakke
Washington University, St. Louis, Mo.	7	Pierre M. Honnell
Wayne University, Detroit, Mich.	5	Edward L. Fairchild
West Virginia University, Morgantown	2	Everette C. Dubbe
Wisconsin, University of, Madison	5	Vincent C. Rideout
Worcester Poly. Institute, Worcester, Mass.	1	Donald C. Alexander
Wyoming, University of, Laramie	6	R. O. Trueblood
Yale University, New Haven, Conn.	1	A. G. Conrad

Total Branches..................129

Scopes of AIEE Technical Committees

The following sections list the names and scopes of the various AIEE technical committees. In accordance with the revised committee structure set in motion by the Board of Directors at a meeting in Worcester, Mass., April 23, 1947 (*EE, Jun '47, pp 597–8*), and approved as latest list of committee functions by the Board of Directors at their meeting in Swampscott, Mass., June 23, 1949, these committees are organized under the following groups: Communication; General Applications; Industry; Power; and Science and Electronics.

Communication Group

COMMITTEE ON AURAL BROADCASTING SYSTEMS

Scope—Treatment of that branch of communications in which the dominant factors are amplitude-modulation and frequency-modulation broadcasting stations, studio equipment, home radio receivers, and other facilities related to the broadcasting of aural programs for entertainment and instruction.

COMMITTEE ON COMMUNICATION SWITCHING SYSTEMS

Scope—Treatment of that branch of communications in which the dominant factors are manual and automatic switching facilities and apparatus associated with communication systems.

COMMITTEE ON RADIO COMMUNICATION SYSTEMS

Scope—Treatment of that branch of communications in which the dominant factors are radio communication systems of all kinds such as point-to-point systems including radio relay for telephone, telegraph, or television; and mobile systems for land, marine, or air-borne services.

COMMITTEE ON SPECIAL COMMUNICATION APPLICATIONS

Scope—Treatment of those branches of the communications field which do not logically fall within the scope of the other communication committees such as: electroacoustics, including wire tape and disk recording; railroad communications; and subjects related to materials and components used in communication apparatus. If the field of application of these materials and components falls also within the scopes of other technical committees, action with those committees may be joint.

COMMITTEE ON TELEGRAPH SYSTEMS

Scope—Treatment of that branch of communications in which the dominant factors are the terminal and intermediate equipment or associated apparatus utilized in providing telegraph services over manual or automatic facilities. It includes also other forms of record communication such as facsimile, telephoto, teletypewriters.

COMMITTEE ON TELEVISION BROADCASTING SYSTEMS

Scope—Treatment of that branch of communications in which the dominant factors are those activities related to television broadcasting systems including studio and mobile pick-up equipment, studio-transmitter links, television receivers, and other facilities associated with the technique of telecasting.

COMMITTEE ON WIRE COMMUNICATION SYSTEMS

Scope—Treatment of that branch of communications in which the dominant factors are wire transmission systems and associated apparatus as applied to open-wire lines, land and submarine cables for providing telephone service, and program transmission for aural and television broadcasting.

General Applications Group

COMMITTEE ON AIR TRANSPORTATION

Scope—Treatment of all matters in which the dominant factors are the design, installation, and performance of airplane equipment, including batteries, generating equipment, voltage regulators, instruments, wiring devices, motors, special controls, reverse current cutouts, bonding, shielding, filtering, inverters, dynamotors, lightning detection and protection, lighting (interior and exterior), system characteristics, weight-power relationships, and heating devices. With respect to communication and navigation; ground lighting; electric testing equipment for measuring strain, vibration, noise, corrosion, and so forth; and electric welding of airplane structures; action should be in co-operation with the respective AIEE technical committees in these fields and similar committees of other organizations.

COMMITTEE ON DOMESTIC AND COMMERCIAL APPLICATIONS

Scope—Treatment of all matters in which the dominant technical factors are the interior supply and utilization of electric power in domestic premises, such as single or multiple dwellings, garages, and other accessory structures, and in institutional buildings such as hospitals, schools, libraries, and so forth. Such subjects as control, interior wiring, heat-operated and motor-operated appliances or equipment for use in domestic, commercial, or institutional premises, including elevators and escalators, are properly within this scope. Subjects relating to the production and application of light, as such, are within the scope of the Production and Application of Light Committee.

COMMITTEE ON LAND TRANSPORTATION

Scope—Treatment of all matters in which the dominant factors are the requirements, design, selection, relation, and operation of electric apparatus and material for transportation (exclusive of air and marine transportation, which are functions of the Air Transportation and Marine Transportation Committees) of passengers and freight and the economic questions incident thereto. Such subjects as the electrification of steam railways, street railways, pantograph trolleys and overhead catenaries, electric locomotives (oil-electric, gasoline-electric, or 3-power locomotives), multiple-unit cars, electric-traction motors, main and auxiliary control equipment, railway substations, mercury-arc rectifier applications, and railways signaling and automatic train control are within the scope of this committee.

COMMITTEE ON MARINE TRANSPORTATION

Scope—Treatment of all matters in which the dominant factors are the application, relation, and installation of electric machinery and materials of whatever nature on shipboard, and the requirements for specialized devices, materials, or constructions peculiar to such application.

COMMITTEE ON PRODUCTION AND APPLICATION OF LIGHT

Scope—Treatment of those matters in which the dominant factor is the application of electric energy through its conversion into light, including necessary materials, devices, and mechanisms, in so far as these matters are considered of interest and value to the members of the Institute. This committee functions as a liaison between the Institute and various organizations dealing with the production and utilization of light, such as the Illuminating Engineering Society, the Optical Society of America, and others. Its activities include translating the theoretical and technical accomplishments of those organizations into terms of the practical aspects of the production and application of light, thereby serving to inform Institute members of important progress in this field. Where problems of electrical supply service, voltage, or distribution are involved, action shall be joint with the Transmission and Distribution Committee.

Industry Group

COMMITTEE ON CHEMICAL, ELECTROCHEMICAL, AND ELECTROTHERMAL APPLICATIONS

Scope—Treatment of all matters in which the dominant factors are the generation of electricity through chemical processes, and the application of electricity to chemical or metallurgical operations (exclusive of electric welding and the phenomena of the arc in so far as it is concerned with the deposition of metal in welding, which is a function of the Committee on Electric Welding, and exclusive of magnetics, which is a function of the Committee on Basic Sciences), including the relations, installation, and operation of the devices necessary thereto, and the requirements of specialized devices, materials, or construction peculiar thereto.

COMMITTEE ON ELECTRIC HEATING

Scope—Treatment of all matters in which the dominant factors are the requirements, selection, installation, and operation of machines, devices, and equipment relating to electric heating of all kinds, including dielectric and induction, radiation, resistance, and high-temperature furnaces. Design and theory of devices shall be handled by consultation with Electronics or other committees as required.

COMMITTEE ON ELECTRIC WELDING

Scope—Treatment of all matters in which the dominant factors are the requirements, design, construction, selection, installation, and operation of machinery and devices relating to electric welding, including studies of the electromagnetic phenomena of the arc in so far as it is concerned with the deposition of metal in welding. Such subjects as electric welding methods and the electric machinery and control equipment specially designed for welding are properly within the scope of this committee.

COMMITTEE ON GENERAL INDUSTRY APPLICATIONS

Scope—Treatment of all matters in which the dominant factors are the requirements, selection, installation, and operation of machinery and devices relating to machine tools and to the processing and/or fabrication (assembly) of nonmetallic materials. Such materials include, textiles, rubber, paper, plastics.

The problems relating to assembly line processes of all materials are considered within the scope of this committee.

COMMITTEE ON INDUSTRIAL CONTROL

Scope—Treatment of all matters in which the dominant factors are the design, construction, and performance of industrial control, and the way in which it serves to govern in some predetermined manner the electric power delivered to the apparatus to which it is connected.

COMMITTEE ON INDUSTRIAL POWER SYSTEMS

Scope—Treatment of all matters in which the dominant factors are the requirements, selection, co-ordination, installation, and operation of machines, devices, and equipment necessary for generating and transmitting electric power within an industrial plant for use solely by that plant. (Actual design of devices and equipment not included.) Design of distribution systems within the industrial plant are a part of the scope of this committee.

When such industrial systems are interconnected with public systems, the action shall be joint with the Committee on Power Generation or on Transmission and Distribution.

COMMITTEE ON MINING AND METAL INDUSTRY

Scope—Treatment of all matters in which the dominant factors are the requirements, selection, installation, and operation of machinery and devices relating to the processing of metal and those relating to mining of any kind.

Matters pertaining to blast furnaces, metal rolling, and metal drawing are properly within the scope of this committee.

COMMITTEE ON SERVOMECHANISMS

Exact title and scope to be announced.

Power Group

COMMITTEE ON CARRIER CURRENT

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of equipment and circuits for the application of carrier currents in the generation, transmission, and distribution of electric power. Included in the scope of this committee shall be treatment of the following:

Carrier current equipment and circuits for
  Relaying
  Control (supervisory, load, frequency, and so forth)
  Metering
  Communication as applied to power system use

also

Line traps
Coupling capacitors
Beamed radio systems for system control

COMMITTEE ON INSULATED CONDUCTORS

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of insulated conductors and the accessories thereto used in the generation, transmission, distribution, and utilization of electric power. Included in this scope shall be treatment of the following:

Cable supply systems (including solid, oil-filled, and gas-filled cables)
Insulated wire and cable
Accessories (including potheads, wiring ducts, and conduit, not including insulated bus runs as in metalclad switchgear)
Structures (joint with Transmission and Distribution Committee)
Cable characteristics
Insulations
Sheaths and coverings
Utilization wiring systems
Special purpose cables
Tests and measurements
Network limiters
Insulated line conductors (specifications)

Matters relating to insulated conductors specifically designed for applications covered by certain other technical committees such as Communication, Transportation, and Electric Heating may be treated jointly with that committee if emphasis is on general principles, or exclusively by the application committee if emphasis is on the particular requirements of the application.

COMMITTEE ON POWER GENERATION

Scope—Treatment of all matters relating to the design, construction, and operation of electric power generating stations, including auxiliary equipment incidental thereto (where such equipment is not otherwise specifically assigned to other technical committees).

Treatment of all matters pertaining to the design, construction, and operation of steam boiler plants, dams, reservoirs, nuclear piles, and other primary sources of energy to prime movers; also the prime movers themselves used in the generation of electric energy.

Treatment of all matters relating to the economics of generation and supply of electric power within individual generating stations.

Included in this scope shall be treatment of the following:

Prime movers (hydro, steam, oil, gas, nuclear, wind power)
Speed governors for prime movers
Station load and frequency control (joint with Systems Engineering Committee)
Control systems (joint with Substation Committee)
Excitation systems and voltage regulators
Station design (generating plant)
Auxiliaries and accessories
Production costs—design and operating economics (separate station)
Co-ordination of prime mover and electric machine design
Bus design (joint with Switchgear and Substation Committees)

COMMITTEE ON PROTECTIVE DEVICES

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of devices and equipment to limit or prevent damage to electric power generation, transmission, or distribution systems, or equipment; such damage arising from excessive current, voltage, or from lightning. Included in this scope shall be treatment of the following:

Capacitors (where used as protective devices)
Lightning protective devices (such as arresters, protector tubes, air gaps, and expulsion gaps)
Fault limiting devices (including neutral grounding devices)
Lightning investigations (joint with Transmission and Distribution Committee)
Reactors and grounding transformers (joint with Transformer Committee)

Matters relating to protective devices specifically designed for applications covered by certain other technical committees such as Industrial Control, Industrial Power Systems, or Communication, may be treated jointly with that committee if emphasis is on general principles or exclusively by the application committee if emphasis is on the particular requirements of the application.

COMMITTEE ON RELAYS

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of protective relays including all matters necessary to the functioning of such relays employed in the generation, transmission, and distribution of electric energy. Included in this scope shall be treatment of the following:

Relays and automatic devices (fault and load discriminating)
Relay protective schemes, including relay co-ordination
Network relays (design, application, and performance)

Matters relating to relays specifically designed for applications, covered by certain other technical committees such as Industrial Control, Communication, and Transportation may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

COMMITTEE ON ROTATING MACHINERY

Scope—Treatment of all matters in which the dominant factors are the requirements, design, construction, and operation of rotating machinery for the generation of electric energy or its conversion into other forms of energy. There shall be included in this scope treatment of the following:

Synchronous machines
Induction machines
D-c machines
Single-phase and fractional-horsepower machines
Motor generator sets
Rotating frequency changers
Rotating phase balancers
Synchronous converters
Insulation and dielectric problems related to rotating machinery

Matters relating to rotating machinery specifically designed for applications covered by certain other technical committees such as Electric Welding, Transportation, or Communication may be treated jointly with that application committee if the emphasis is on general principles; or exclusively by the application committee if the emphasis is on the particular requirements of the application.

COMMITTEE ON SUBSTATIONS

Scope—Treatment of all matters in which the dominant factors are the electrical and structural design, construction, installation, operation, and control of automatic, semiautomatic, and nonautomatic substations, including switching and transformer stations.

Included in the scope of this committee shall be treatment of the following:

Automatic, semiautomatic, and nonautomatic substations
Switching stations
Fundamental single-line wiring diagrams
Bus design (joint with Switchgear and Power Generation Committee)
Automatic and supervisory control systems (joint with Power Generation Committee)
Supervisory control devices
Structural arrangements for substations
Telemetering (joint with Instruments and Measurements Committee)
Insulation co-ordination (joint with Transmission and Distribution Committee)

COMMITTEE ON SWITCHGEAR

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of devices or assembled gear to establish (make), interrupt, or change connections in an electric circuit under normal or abnormal conditions. Included in this scope shall be treatment of the following:

Power circuit breakers
Large air circuit breakers
Low-voltage air circuit breakers
Switchgear assemblies
Switches
Network protectors (design and application)
Bus design (joint with Power Generation and Substations Committees)
Insulation, insulators, and hardware for switchgear
Automatic reclosers
High-voltage fuses and cutouts (above 600 volts)

Matters relating to switchgear or switchgear devices specifically designed for applications covered by certain other technical committees such as industrial control, communication, electronics, and transportation may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

COMMITTEE ON SYSTEM ENGINEERING

Scope—Treatment of all matters in which the dominant factors are the requirements, planning, co-ordination, operation, and economics of interconnected electric generating, transmission, and distribution systems. Included in this scope shall be treatment of the following:

Interconnected system planning
Frequency and load control (joint with Power Generation Committee)
Load dispatching
Economics of system and unit operation
Engineering of system expansion
Interconnection contracts

COMMITTEE ON TRANSFORMERS

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of transformers, reactors, and other similar equipment. Included within this scope shall be treatment of the following:

Transmission and distribution transformers
Voltage and load regulators (step and induction regulators)
Reactors and grounding transformers (joint with Protective Devices Committee)
Speciality transformers and regulating transformers
Railway service transformers
Test transformers
Constant current transformers
Insulating fluids
Insulation and dielectric problems relating to transformers
Insulators and hardware with transformers
Potential devices
Bushing and Instrument
Transformers
} with co-ordination with Relay, Switchgear, and Instruments and Measurements Committees

Matters relating to transformers and regulators specifically designed for applications covered by certain other technical committees such as Relays, Electronics, Protective Devices, Communication, may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

COMMITTEE ON TRANSMISSION AND DISTRIBUTION

Scope—Treatment of all matters in which the dominant factors are considerations of economical and technical design, theoretical and experimental performance, installation, and service operation of that part of electric power systems which serve to transmit electric energy between the generating source or substation and the service.

Treatment of all matters involving substations themselves including switching and transforming stations are not within the scope of this committee, except in the broad aspects of the application of a substation as a whole.

Treatment of matters involving industrial distribution systems shall not be included within this scope unless such systems are interconnected with an electric power utility, in which case the action shall be joint with the Committee on Industrial Power Systems.

Included in this scope shall be treatment of the following:

Overhead and underground transmission and distribution systems
Overhead conductors
Fault current studies
System stability
Lightning investigations (joint with Protective Devices Committee)
Network systems and studies
Insulated line conductors (properties related to system problems)
Structural co-ordination
Insulation co-ordination (joint with Substation Committee)
Inductive co-ordination
Corona
Towers, poles, insulators, and hardware
Capacitors (except those used for protective devices)

Science and Electronics Group

COMMITTEE ON BASIC SCIENCES

Scope—Treatment of all matters in which the dominant factor is electrophysics, and which are of such novel character as to be unapplied in any apparatus or field of application within the scopes of the other technical committees, or which are of such generality as to be significant within the scopes of several technical committees. Such subjects as general circuit theory, electrostatics, mathematical treatises, magnetics, general electrical units, and nomenclature are properly within the scope of this committee.

COMMITTEE ON COMPUTING DEVICES

Scope—Treatment of all matters in which the dominant factors are the requirements, design, construction, selection, installation, scope, and operation of machinery and devices relating to computing devices, including studies of the electromagnetic, electronic, and mechanical phenomena of such devices.

Fundamental mathematic, electronic, and properties of materials entering into these devices are not included.

COMMITTEE ON ELECTRONIC POWER CONVERTERS

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of equipment and circuits for the electronic conversion of electric energy into other phases of electric energy in the generation, transmission, distribution, and utilization of electric power. This scope shall not include hot-cathode-type converters which have been assigned to the Hot Cathode Electronic Power Converters Subcommittee of the Electronics Committee. There shall be included in this scope treatment of the following:

Electronic converters for motor control (joint with Industrial Control Committee)
Electronic power rectifiers and inverters
Electronic frequency changers

Matters relating to electronic converters specifically designed for applications covered by certain other technical committees such as Transportation, Industrial Power Systems, Electrochemical Applications, and the committees in the Communication Group, may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

COMMITTEE ON ELECTRONICS

Scope—Treatment of all matters in which the dominant factor is electronics, particularly those dealing with the design, characteristics, or behavior of devices of an electronic nature, or of the circuits associated with them. The treatment of complete equipments or systems may be considered within the scope of this committee if they depend predominantly on electronic devices for their operation. If the field of application of such equipments or systems falls also within the scope of other technical committees, action with those committees may be joint.

COMMITTEE ON INSTRUMENTS AND MEASUREMENTS

Scope—Treatment of all matters in which the dominant factor is the measurement of electrical quantities, both absolute and relative, and the measurement of other quantities by electrical methods, including the devices necessary thereto. Where novel instruments and novel methods of electrical measurement are in papers, even though measurement is not the prime objective, then action shall be joint with the respective technical committee concerned.

Telemetering is assigned primarily to the

Committee on Instruments and Measurement and handled by a joint subcommittee comprised of members of both the Committees on Substations and Instruments and Measurements. Telemetering problems in connection with automatic stations will be assigned by the chairman of the Committee on Instruments and Measurements to members of the subcommittee who are also members of the Committee on Substations. Telemetering problems of a more general nature will be assigned by him to members of both main committees, and where the problem is simply measurements it will be assigned only to members of the Committee on Instruments and Measurements (as per joint agreement between the Committees on Automatic Stations and Instruments and Measurements, January 29, 1935).

COMMITTEE ON METALLIC RECTIFIERS

Scope—Treatment of all matters in which the dominant factors are metallic rectifiers, (extended surface metallic rectifiers), particularly those dealing with the design, characteristics, and behavior of devices relating to "dry"-type rectifiers, including those used in low-power applications, those used as modulators, demodulators, detectors, and instrument rectifiers. If the field of application of such devices falls within the scopes of other technical committees, action with those committees may be joint.

COMMITTEE ON NUCLEONICS

Scope—Treatment of all matters in which the dominant factor is nucleonics, particularly that dealing with the design, characteristics, or behavior of devices of a nucleonic nature, or of the systems associated with them. The treatment of complete equipments or systems may be considered within the scope of this committee if they depend predominantly on nucleonic principles for their operation. If the field of application of such equipments or systems falls also within the scopes of other technical committees action with those committees shall be joint.

COMMITTEE ON THERAPEUTICS

Scope—Treatment of all matters in which the dominant factors are the applications of electric power to sanitation equipment, such as air-cleaning and sterilizing devices, and to the promotion of health and the analysis and treatment of disease or defects of the human body, such as X-ray equipment, diathermic equipment, cardiographs, investigations not directly applying to the human body but relating to health, and electric devices suitable for such purposes; the study of harmful effects of electric currents and radiations of electric devices upon the human body and means for the prevention of such effects, and so forth, are properly within the scope of this committee.

Where certain devices are suitable for both therapeutic and industrial purposes, such as some X-ray equipment, or for therapeutic and other scientific investigations, or for sanitation and air-conditioning of domestic and commercial premises, action shall be joint with the Industrial Power Systems Committee, the Basic Sciences Committee, or the Domestic and Commercial Applications Committee, respectively; also, when appropriate, with the Safety Committee.

INSTITUTE ACTIVITIES

1949 AIEE Fall General Meeting to Be Held in Cincinnati, Ohio

Plans for the AIEE Fall General Meeting (formerly known as the AIEE Midwest General Meeting) which is to be held at the Netherland Plaza Hotel in Cincinnati, Ohio, October 17–21, 1949, are fast materializing. Besides an outstanding technical program, the meeting committee is hard at work planning for the entertainment and comfort of all visitors.

The Entertainment Committee has great plans for the entertainment of both men and women. The stag smoker on Tuesday night and the dinner dance on Wednesday night, in the beautiful "Pavilion Caprice" of the Netherland Plaza Hotel will certainly be occasions to be remembered by all.

The Ladies Committee has arranged a diversified program that will meet every expectation and they guarantee not a single dull moment for the ladies. The General Committee is particularly hopeful that most members will make a special effort to encourage their wives to accompany them to the Fall General Meeting.

Besides the "big occasions" there will be many other entertainment features such as, ice hockey games, theatres, and some of the most luxurious night clubs in the midwest.

INSPECTION TRIPS

The Inspection Trip Committee has completed arrangements for an interesting group of inspection trips. These trips will include visits to the following places of interest:

1. Baldwin Piano Company
2. Crosley television station
3. Engineering Society of Cincinnati
4. Fisher Body plant
5. Miami Fort generating station
6. Cincinnati Machine Tool Colony, including the Cincinnati Milling and Grinding Machine, Inc., Cincinnati Bickfort Tool Company, and Cincinnati Planer Company
7. Procter and Gamble Company

TECHNICAL PROGRAM

The technical program for the Fall General Meeting is rapidly being completed. At present, 25 sessions and conferences are being planned on the following subjects:

Transmission and distribution
Rotating machinery
Electronic power converters
Relays
Insulated conductors
Conformal mapping
Railroad communication
Voltage induction
Coaxial systems
Protective devices
Substations
Radio
Speed governing
Television
Probability methods
Industrial power systems
Industrial control
System economics
Aluminum
Instruments and measurements
Machine tool industry

Cincinnati industries will be well represented, especially in the radio and television, power and machine tool fields.

It will be remembered that the Fall General Meeting is the third such meeting of the Institute. The first was sponsored by the Chicago Section in 1947, and last year Milwaukee, Wis., was host to what was then known as the Midwest General Meeting. With the inauguration of this meeting, the number of general meetings was brought up to four per year, namely, the Winter, Pacific, Summer, and Fall General Meetings. Judging from the demand for sessions and the number of papers offered, the addition of this meeting certainly seems to have been justified.

HOTEL RESERVATIONS

In the Hotel Netherland Plaza all rooms are outside rooms with tub, shower, and four station radio. Room rates per day are as follows:

Single room	$ 4.00–$10.00
Double bedroom for two	$ 8.00–$12.00
Twin bedroom for two	$ 9.00–$13.00
Suite: parlor and bedroom	$18.00–$35.00

All requests for room reservations should be sent directly to the Hotel Netherland Plaza, Fifth and Race Streets, Cincinnati 2, Ohio. Members are urged to send in their requests early. The Hotel Netherland Plaza will place overflow reservations in adjacent hotels, including the Terrace Plaza, Hotel Gibson, and Hotel Sinton at comparable rates.

MEETING COMMITTEES

Members of the Fall General Meeting Committee making arrangements are

E. S. Fields, *Chairman;* R. J. Rockwell, *Vice-Chairman.* J. P. Quitter, *Secretary;* W. H. McNutt, *Treasurer;* J. C. Strasbourger, R. E. Stoppel, F. E. Wiatt.

The chairmen of the various subcommittees are

A. C. Burroway, E. F. Nuezel, *Technical Program;* W. T Pavely, *Inspection Trips;* S. B. Storer, *Entertainment;* J. A Noertker, *Transportation;* D. T. Michael, *Registration;* F. W. Willey, *Finance;* R. E. Colado, *Publicity;* Mrs. J. A Noertker, *Ladies;* H. E. Barnett, *Hotel and Equipment.*

The Herman Schneider Foundation building, home of the Engineering Society of Cincinnati, and headquarters of the Technical and Scientific Societies Council of Cincinnati, which is to be visited on an inspection trip during the Fall General Meeting

Committee for 1950 Summer and Pacific General Meeting Named

Past President Everett S. Lee has appointed the following persons to the general committee which will make plans for the Summer and Pacific General Meeting, to be held in Pasadena, Calif., June 12–16, 1950: Fred Garrison, *Chairman;* M. V. Eardley, *Vice-Chairman;* E. L. Bettannier, *Secretary;* J. H. Vivian, *Treasurer.*

The following have been named subcommittee chairmen:

Harry Lott, *Technical Program;* E. W. Morris, *Registration;* Mark Sawyer, *Hotels;* E. W. Rockwell, *Transportation;* Bradley Cozzens, *Finance;* William Kyte, *Publicity;* G. F. Rucker, *Trips;* Dr. G. T. Harness, *Student Relations;* H. S. Warren, *Sports;* Chester Schweers, *Entertainment and Program;* Mrs. Fred Garrison, *Ladies' Entertainment.*

Next year, it is planned to combine the Summer General Meeting and the Pacific General Meeting into one. It will be titled the Summer and Pacific General Meeting.

New Prize Rules for AIEE Technical Papers Approved by AIEE Board of Directors

The following constitute the new rules for the award of prizes for AIEE technical papers as approved by the AIEE Board of Directors at their annual meeting on June 23, 1949, during the AIEE Summer General Meeting in Swampscott, Mass.

INTRODUCTION

The AIEE has established a series of prizes which are available for annual award to members for outstanding papers presented at its meetings.

Each prize consists of a sum of money and/or a Certificate of Award. Appropriate recognition will be given in *Electrical Engineering* and in the AIEE "Year Book."

PRIZES

The following summarizes the awards available each year in each classification.

1. *Institute*

Class	First Prize	Second Prize
(*a*). Power	$100 and certificate	Certificate
(*b*). Industry	$100 and certificate	Certificate
(*c*). Communication	$100 and certificate	Certificate
(*d*). General Application	$100 and certificate	Certificate
(*e*). Science and Electronics	$100 and certificate	Certificate
(*f*). Best Student Paper	$100 and certificate	Certificate

2. *District*

Class	First Prize	Second Prize
(*a*). Best paper, any class	$75 and certificate	$50 and certificate
(*b*). Best paper presented by undergraduate Student member in District competition	$25 and certificate	Certificate

3. *Section*

$100 to be divided at the discretion of the Section with a maximum of $50 for any one prize, and certificate for each winner.

4. *Branch* (*Undergraduate*)

Class	First Prize	Second Prize
(*a*). Best Paper	$10 and certificate plus an allowance of seven cents per mile one way to the District Student prize paper competition	Certificate

Coauthors will split prize; each will receive a certificate. Equivalent gift may be substituted for the monetary prize.

PERSONS ELIGIBLE

To compete for these awards requires only that the author (or one of the coauthors) be an eligible member of the Institute, a Fellow, Member, Associate, or enrolled Student member in good standing, and that the paper be presented at a qualified technical meeting of the AIEE; the Institute Winter, Summer, Fall, or Pacific General Meeting; District meeting; Section (including technical group and Subsection) meetings; or Branch meetings. District, Section, and Branch prizes will be limited to authors who are resident within the respective territories covered.

ENTRANCE REQUIREMENTS

All papers presented at District, Section, Branch, or Student meetings will be considered for *Institute* and *District* awards, if submitted in triplicate to the Institute or District Secretary before September 15, of the following administrative year, and accompanied by a written statement as to when and where the papers were presented. The date of consideration for District awards may be varied by the District Executive Committee at its discretion.

When three or more papers are submitted for *Section* or *Branch* competition to the respective secretaries, arrangements shall be made for presentation before the Section or Branch at a meeting set aside for that purpose and committees selected to judge each such contest.

All papers approved by the Technical Program Committee which are presented at the Winter, Summer, Fall, or Pacific General Meetings of the Institute will be considered for *Institute* Prizes without formal offering in competition.

All papers approved by the Technical Program Committee as described in the foregoing and those which are approved by the Technical Program Committee and presented at District meetings will be considered for *Institute* and *District* prizes without formal offering in competition.

GENERAL INFORMATION

1. *Presentation of Awards*

Presentation of awards will be made: annually at the regular Winter General Meeting for Institute prizes; at a meeting within the District for District prizes or at a meeting designated by the District Executive Committee; at appropriate Section meetings for Section prizes; and at Branch meetings for Branch prizes.

2. *Where Insufficient Papers Are Submitted*

When in the opinion of the Committee on Award the number of papers in a given class is not sufficient to constitute a real competition, the award will be withheld. In this case these papers will be considered with others presented in the following year.

3. *Date of Presentation*

All prizes will be awarded on the basis of papers presented during the administrative year, August 1 to July 31. (Except as varied by District Executive Committee to cover District competition and by Sections to cover Section competition.)

BASIS OF GRADING

1. *Institute, District, and Section Papers*

The valuations which govern the grading of papers for the purpose of awarding best paper prizes are

Analysis of subject—15 per cent
Logical presentation—15 per cent
Originality—15 per cent
Unity—15 per cent
Value in electrical engineering field—40 per cent
(*Except in Section competition where value will be rated 20 per cent and oral presentation 20 per cent*)

2. *District Branch and Branch Papers*

As the objective of Student papers differs from that of the more advanced papers, the basis of grading given in the following has been adopted. It is not the primary purpose of Student papers to contribute to the technical advancement of the profession; they should constitute a vehicle for the training and stimulation of future contributors to the profession. To this end greater emphasis has been placed on written presentation and the exercise of engineering thinking than on technical value. Written presentation shall be given a weighting of two compared with one for oral presentation.

A. *Basis for Grading Written Presentation:*

Originality—20 per cent
Survey of subject (analytical procedure)—15 per cent
Importance—15 per cent
Appropriateness—10 per cent
Mode of Expression—

(*1*). Logical organization of material for clarity, forcefulness, and interest. Appropriate headings are essential. (10 per cent)

(*2*). Concise and coherent expression of thoughts in good English and with proper choice of words. (10 per cent)

(*3*). Effective and judicious use of pictorial and graphical presentation. (10 per cent)

Adequate introduction and closure—10 per cent

B. *Basis of Grading for Oral Presentation:*

Speaking technique—35 per cent
Style (organization of material)—35 per cent
Introduction and conclusion—15 per cent
Discussion—15 per cent

COMMITTEE ON AWARD OF INSTITUTE PRIZES

1. *Institute*

The Committee on Award of Institute Prizes shall be appointed by the Institute President and shall consist of not less than five Members or Fellows of the Institute.

2. *District*

The Committee on Award of District Prizes shall be appointed by the District Vice-President and shall consist of not less than three Members or Fellows of the Institute. Judges of oral presentation of Student papers need not be same as judges of written presentation and they may include Associate or non-Institute members when necessary.

3. *Section*

The Committee on Award of Section Prizes shall be appointed by the Section Chairman and shall consist of not less than three Members or Fellows of the Institute.

4. *Branch*

The Committee on Award of Branch Prizes shall be appointed by the Student Counselor and shall consist of not less than three Associates, Members, or Fellows. When necessary, a non-Institute member may be selected.

EFFECTIVE DATE OF RULES

These rules become effective with the administrative year beginning August 1, 1949.

PROCEDURE FOR REVISION

These rules are subject to revision annually by the Board of Directors of the Institute.

AIEE Textile Industry Conferences Held in Boston and Atlanta Last May

Electrical engineering problems in the textile industry was the subject of two AIEE technical conferences held last May. The first took place in Boston, Mass., at the Hotel Kenmore, May 3, 1949, and the second in Atlanta, Ga., at the Young Men's Christian Association auditorium of the Georgia Institute of Technology, May 27–28, 1949. These gatherings represented two more conferences in the series of ten held since the special AIEE conference type of meeting was started in 1948 (*EE, Feb '48, p 189*). This type of meeting is designed to explore thoroughly a limited field and to afford specialists in that field an opportunity to discuss mutual technical problems.

In this instance, two meetings were held on the one subject, one in each of the two principal geographic areas concerned with the textile industry, so that engineers in the industry could find it convenient to attend.

BOSTON CONFERENCE

The Boston meeting was sponsored by the Textile Industry Subcommittee of the Committee on General Industry Applications in co-operation with the Boston Section of AIEE. Seven papers and two moving pictures were presented during the two sessions of the meeting. Subjects covered by the papers ranged from cloth production in the loom to cloth finishing, including cloth printing, straightening, and electronic instrumentation as an aid to these and other processes.

In spite of the change in meeting place of the conference from the Massachusetts Institute of Technology, Cambridge, Mass., to the Kenmore Hotel and the inclement weather, some 65 persons attended.

F. D. Snyder, Westinghouse Electric Corporation, Boston, Mass., who is chairman of the Textile Industry Subcommittee, opened the meeting by reviewing the work of the subcommittee and enumerating some of the problems facing the textile industry. He also emphasized the mutual benefit of exchanging ideas and discussing problems in such a meeting as was being held then.

ATLANTA CONFERENCE

Approximately 95 persons, mostly engineers and executives of Southeastern textile mills, attended the conference in Atlanta, the first such conference in the Southeast.

Again the meeting was sponsored by the Textile Industry Subcommittee of the General Industry Applications Committee, this time in co-operation with the Engineering Extension Division of the Georgia Institute of Technology and the Georgia Section of AIEE.

H. S. Colbath, Plant Engineer, Bibb Manufacturing Company, Macon, Ga., presided over the first session, in which electronic instrumentation, loom research, and electric drives for looms, were discussed.

C. A. Collier, Vice-President, Georgia Power Company, Atlanta, Ga., was the speaker at the luncheon. He talked on the responsibilities of business towards its employees, and the advantages of a healthy and contented working force.

Harry C. Uhl, Electrical Engineer, Avondale Mills, Sylacauga, Ala., directed the proceedings at the second session on May 27. Fire hazards, methods of obtaining traverse motion, and electric equipment for textile machines were among the topics covered.

Presiding over the last session, held May 28, was S. A. Bobe, Westinghouse Electric Corporation, Atlanta, Ga. Papers on electrostatic air cleaning and textile education in Georgia were delivered.

Both Mr. Bobe and Mr. Uhl are members of the Textile Industry Subcommittee.

There will be no publication in pamphlet form of the proceedings of the Boston and Atlanta conferences. However, some digests appear in this issue (*pages 797–8*).

Future AIEE Meetings

Fall General Meeting
Netherland Plaza Hotel, Cincinnati, Ohio
October 17–21, 1949
(*Final date for submitting papers—closed*)

AIEE/IRE Conference on Electronic Instrumentation in Nucleonics and Medicine
Hotel Commodore, New York, N. Y.
October 31–November 2, 1949

Winter General Meeting
New York, N. Y.
January 30–February 3, 1950
(*Final date for submitting papers—November 1*)

AIEE Conference on Electric Power Supply for Industrial Plants
Pittsburgh, Pa.
April 1950

AIEE Conference on Meeting Load Demands With Limited Reserve
Pittsburgh, Pa.
April 1950

AIEE Conference on Electrical Engineering Problems in the Rubber and Plastics Industry
Akron, Ohio
April 1950

AIEE Conference on Electric Welding
Detroit, Mich.
April 5–7, 1950

North Eastern District Meeting
Providence, R. I.
April 26–28, 1950
(*Final date for submitting papers—January 26*)

Great Lakes District Meeting
Jackson, Mich.
May 11–12, 1950
(*Final date for submitting papers—February 10*)

Summer and Pacific General Meeting
Huntington Hotel, Pasadena, Calif.
June 12–16, 1950
(*Final date for submitting papers—March 14*)

1950 Fall General Meeting
Oklahoma City, Okla.
October 23–27, 1950
(*Final date for submitting paper—July 25*)

Secretary Henline to Attend London Conference of Engineering Societies

AIEE Secretary H. H. Henline has been designated to represent AIEE at a conference of representatives of engineering societies of Western Europe and the United States which is to be held in London, England, September 19–23, 1949. This is the first AIEE participitation in such a gathering which will include representatives of engineering societies from Belgium, Denmark, France, Holland, Norway, Sweden, Switzerland, the United Kingdom, and the United States.

The aims and objects of the conference include

1. To develop direct relationships between the participating societies on a basis of mutual understanding for the advancement of engineering science.
2. To provide a means whereby questions of domestic concern to the participating societies can be discussed.
3. To give all proper support to each participating society within its own country.
4. To act as a focus of the professional engineering opinion of the participating societies.
5. To co-operate, as may be considered desirable, with international organizations and to support and supplement their work.

Long an officer of the Institute, Mr. Henline joined the headquarters staff as assistant national secretary in 1927, was appointed national Secretary in 1933, and has held that post ever since. His long experience in Institute affairs should prove to be extremely valuable in the discussion of mutual problems with these other engineering organizations.

Lamme Medal Nominations to Be Submitted by December 1

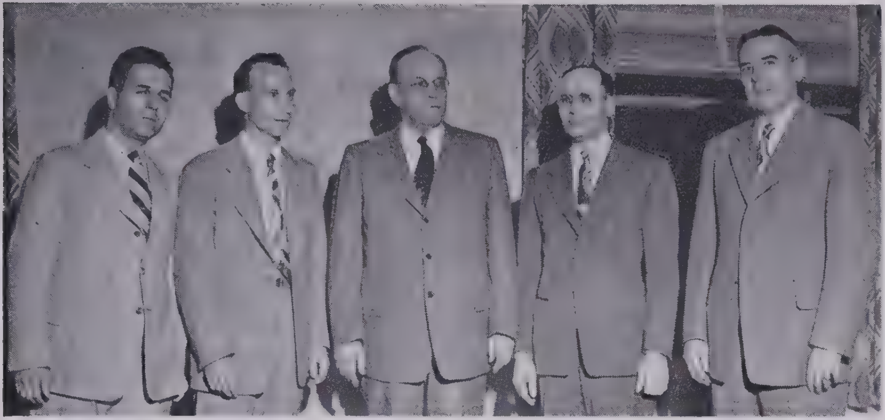
Members of the Institute again are reminded that they have an opportunity to submit nominations for the 1949 Lamme Medal. All nominations must be received not later than December 1, 1949. Details regarding qualifications have been published in *Electrical Engineering* (*EE, June '49, p 547*).

The 1948 Lamme Medal was awarded to Dr. V. K. Zworykin, Vice-President and Technical Consultant, RCA Laboratories Division, Radio Corporation of America, Princeton, N. J., "for his outstanding contribution to the concept and design of electronic apparatus basic to modern television." The medal was presented to him at the Summer General Meeting (*EE, Aug '49, p 698*). Full texts of the addresses at the presentation ceremony appeared in the August issue (*pp 668–72*).

Vice-President G. W. Bower Addresses Lima Subsection

The first annual meeting of the Lima Subsection (Dayton Section) was held June 10, 1949, in the Ohio Power Company Auditorium. This was an outstanding meeting with Vice-President G. W. Bower speaking on "Institute Affairs." C. G. Veinott, Vice-Presidential nominee from the Middle Eastern District to succeed Mr. Bower, was also present. Results of

New Officers of the Lima, Ohio, Subsection



Newly elected officers of the Lima, Ohio, Subsection, Dayton Section, are, left to right: F. C. Horn, Lima Electric Motor Company, Director; W. R. Ankrom, Ohio Power Company, Director; B. O. Austin, Westinghouse Electric Corporation, Chairman; O. M. Swain, Westinghouse Electric Corporation, Secretary-Treasurer; E. S. Reed, Westinghouse Electric Corporation, Assistant Secretary. H. C. Doughty, Ohio Power Company, Vice-Chairman, does not appear in this picture

the election of officers for the Subsection were announced.

B. O. Austin, Manager, Control Section, Aircraft Engineering Department, Small Motor Division, Westinghouse Electric Corporation, was named Chairman of the Subsection for the coming year. Other officers elected were H. C. Doughty, Ohio Power Company, *Vice-Chairman;* O. M. Swain, Westinghouse Electric Corporation, *Secretary-Treasurer;* E. S. Reed, Westinghouse Electric Corporation, *Assistant Secretary;* and F. C. Horn, Lima Electric Motor Company, *Director.* W. R. Ankrom, Ohio Power Company, also continues as Director another year.

Chairman W. R. Appleman and several members of the Dayton Section attended the meeting. Also present were Chairman Walls and a large group from the Ohio Northern University Student Branch.

A social hour with refreshments at the close of the meeting allowed the members to meet the speaker and informally discuss Institute activities.

Philadelphia Section Holds Annual Prize Papers Night

At the final meeting of the 1948–49 season, the AIEE Philadelphia Section held its annual "Prize Papers Night." The winning papers in the section competition were presented by their authors at the meeting. First honor awards of $25 each were given for the following papers:

Power Systems: "Transient and Cyclic Load Temperature Calculations for Cable Systems," by J. H. Neher, Philadelphia Electric Company

Electronics and Communications: "Automatic Range-Adjusting Radio Sonde Recorder," by G. E. Beggs, Jr., Leeds and Northrup Company

Instruments and Measurements: "Graphical Method for Estimating the Performance of Distance Relays During Faults and Power Swings," by A. R. Van C. Warrington, General Electric Company

Basic Sciences: "Design of a Digital Computing Machine," by T. K. Sharpless, Technitrol Engineering Company

Student Papers: "Method of Indicating Phase Displacement Between Periodic Electrical Waves," by M. M. Carpenter, Jr., University of Delaware

M. M. Carpenter, Jr., of the University of Delaware, was awarded a special prize of ten dollars for the best presentation.

COMMITTEE NOTES •

Editor's Note: This department has been created for the convenience of the various AIEE technical committees. It will include brief news reports of committee activities and proposed plans for such projects as special technical conferences and sessions at general meetings. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Science and Electronics Group

National Instrument Conference Scheduled for St. Louis

The Fourth National Instrument Conference and Exhibit will be held in St. Louis, September 12–16, 1949. It will be sponsored by the Instrument Society of America, and technical sessions on various phases of instrumentation are to be held during the conference. These sessions will be arranged by the Instrument Society of America, the AIEE Committee on Instruments and Measurements, the Industrial Instruments and Regulators Division of the American Society of Mechanical Engineers, and the American Institute of Physics.

Three previous conferences and exhibits were held; one in Pittsburgh, Pa., one in Chicago, Ill., and last year one was held in Philadelphia, Pa. Last year was the first year that AIEE participated in the conferences. Two sessions were arranged by the Instruments and Measurements Committee and the attendance at each session was approximately 300. This year, through the efforts of J. P. Scott, of the Instruments and Measurements Committee, who was appointed Chairman of the committee to make the necessary arrangements for AIEE participation in the conference, two technical sessions have been scheduled.

On Thursday, September 15, 1949, at 2:30 p.m., the AIEE session on electronic instruments will be held under the chairmanship of J. G. Reid, Jr., National Bureau of Standards, Washington, D. C. Papers to be presented include

A Wide Band D-C Amplifier Stabilized for Gain and for Zero. *A. J. Williams, Jr., W. G. Amey, W. McAdam,* Leeds and Northrup Company, Philadelphia, Pa.

A Regulated, Adjustable Low-Voltage D-C Supply for Electrolysis and Other Use. *M. L. Greenough, W. E. Williams, Jr.,* National Bureau of Standards Washington, D. C.

Radiosonde Instrumentation. *Walter R. Beam,* Washington Institute of Technology, Washington, D. C.

Velocity and Flow Measurements With an Improved Thermal Instrument. *C. E. Hastings,* Hastings Instrument Company, Jampton, Va.

On Friday, September 16, 1949, at 2:30 p.m., an AIEE session on electrical instruments and measurements is scheduled. Chairman of the session will be J. P. Scott, Union Electric Company, St. Louis, Mo. Four papers are to be presented, including

A New Thermal Converter for Telemetering and Totalizing. *William C. Downing,* Sangamo Electric Company, Springfield, Ill.

A New Expanded Scale A-C Voltmeter. *N. P. Millar,* General Electric Company, West Lynn, Mass.

Electrical Measuring Instruments, Developments and Standardization. *D. A. Young,* Westinghouse Instruments and Engineering Department, Newark, N. J.

V-2 Rocket Instrumentation. *George J. Fiedler,* Sverdrup and Parcel Inc., Consulting Engineers, St. Louis, Mo.

Mr. Scott has been very ably assisted in organizing the AIEE program for the conference by J. G. Reid, Jr., and Dr. W. R. Clark, who are representing the Instruments and Measurements Committee, and the following members of the St. Louis Section of the AIEE, who have been appointed to the committee to take care of general arrangements: R. E. Schoetker, R. W. Gaskins, E. S. Rehagen, C. W. Schemm, and P. R. Watson.

The Committee on Instruments and Measurements takes this opportunity to express its appreciation of the splendid co-operation of the St. Louis Section under the guidance of its Chairman, R. C. Horn, in making the necessary arrangements for the technical committee's participation in this conference.

Joint Subcommittee on Telemetering. (*C. K. Duff, Chairman; W. K. MacAdam, Secretary.*) This joint subcommittee is comprised of members of the Instruments and Measurements Committee and of the Substations Committee, to co-ordinate matters relating to telemetering, in which the AIEE has maintained a specific interest for some 20 years.

In 1948 the joint subcommittee completed revision of a report on "Telemetering, Supervisory Control, and Associated Circuits," and it is now available from AIEE.

(Orders for this report together with remittance of $2 per copy, $1 to AIEE members, should be sent to AIEE Order Department, 33 West 39th Street, New York 18, N. Y.).

During the past few months the subcommittee has been making contacts with a recently formed body known as the National Telemetering Forum, which is interested mainly in telemetering from mobile devices such as rockets. This field is emerging only now from security regulations, and an insight into it was given in a session on radio telemeter instrumentation sponsored by the Joint Subcommittee on Electronic Instruments at the recent Summer General Meeting at Swampscott, Mass. The two joint subcommittees have arranged for close liaison with the National Telemetering Forum, whose chairman, W. J. Mayo-Wells, is a member of the AIEE and recently has accepted membership on the Joint Subcommittee on Telemetering.

The subcommittee is working at present on definitions of telemetering terms, a subject which is also active among members of the National Telemetering Forum. A number of revised definitions and new terms have been suggested. A proposed new term of broader application is the coined word *metrant*, to signify "the thing being measured."

Joint Subcommittee on Nucleonic Instruments. (*G. W. Dunlap, Chairman; E. E. Goodale, Secretary.*) The subcommittee sponsored a conference session on nucleonic instruments at the Summer General Meeting at Swampscott, Mass.

Previously, similar conferences had been sponsored at the 1948 Winter General Meeting in Pittsburgh, and at District meetings in Spokane and Washington. It is planned to sponsor sessions in the future only at the general meetings, but to offer assistance to any local group desiring to arrange such programs.

In co-operation with the other subcommittees of the Nucleonics Committee, this subcommittee is arranging to sponsor a series of papers in *Electrical Engineering* on special subjects of interest to the membership. The subcommittee will concern itself with papers on nucleonic instruments.

The subcommittee members also are cooperating with the National Research Council on the forthcoming Nucleonics Glossary to the extent of review and suggestion.

Power Group

Committee on Transmission and Distribution. (*I. W. Gross, Chairman; S. B. Crary, Vice-Chairman; R. E. Pierce, Secretary.*) An excellent example of co-operation between the Edison Electric Institute and AIEE is offered by the activity that the Transmission and Distribution Committees of the two organizations are carrying out jointly. Subcommittees of the two committees have just completed a questionnaire which will be submitted to the utilities of the country having transmission systems in excess of 100 kv. The Edison Electric Institute will circularize utilities having membership in their organization, and AIEE will circulate other utilities. This activity will cover the characteristics of transmission lines in this range, the types of faults and their causes, and the frequency of occurrence of such faults. When completed, the analysis will provide information of value in improving service and in guiding the design and layout of future transmission systems.

AIEE PERSONALITIES.....

R. S. Gardner (A '49) has joined the headquarters staff of AIEE where his duties are assisting the AIEE Secretary in matters covering technical committee activities and directing the administrative and procedural aspects of Special Technical Conferences. In addition, he is the Secretary of the following committees: Technical Activities, Industry Co-ordinating, Power Co-ordinating and Electric Welding. Also, he is a member of the Board of Directors of the Engineering Societies Personnel Service, Inc., and a Military Engineer member of the American Society of Military Engineers. Mr. Gardner is a native of Virginia, graduating from the Virginia Polytechnic Institute in 1922 with a Bachelor of Science degree in electrical engineering. He subsequently joined the General Electric Company in Schenectady, New York, as Test Engineer. Later, he did design, research, and production engineering for the company, where he remained until 1926. After a year, as Electrical Layout Engineer with the Ryan Construction Company, Troy, New York, he became associated with Underwriters Laboratories, Inc., New York, N. Y., in 1927, as an electrical engineer. Seven years afterwards, he joined the firm of M. R. Scharf, Consulting Engineer, New York, N. Y., where he handled the evaluation of electrical substation equipment, and in 1935 he was designated Engineer-in-Charge of Federal Government construction (including electrical design) programs and compiling of engineering statistical data in New York, N. Y. Here, his duties were largely administration, planning, checking and approving design and project work, executive conferences, engineering reports, and so on. During that time, he supervised personnel numbering approximately 200, including engineers, designers, draftsmen, technicians, foremen, skilled tradesmen, clerks, and so forth. From 1941 to 1944, Mr. Gardner was a production analyst for the War Production Board, contacting manufacturers in the production control of war items (mostly electrical) and then a specification engineer for the Treasury Department. Prior to joining the AIEE Staff, he worked as assistant chief engineer and as an electrical designer for New York companies, handling electronic and radar equipment, and electric generating power plants respectively, and also as a self-employed industrial consultant. Mr. Gardner stands ready to serve officers, members, and committees of the Institute.

R. S. Gardner

H. M. Trueblood (A '17, F '40), Assistant Director of Transmission Engineering, Bell Telephone Laboratories, New York, N. Y., has retired after 31 years of service with the Bell System. His specialty was the development of methods and procedures for the protection of telephone service, plant, and personnel from the effects of induction from power and electrified railway circuits. As Protection Development Director, to which post he was named in 1938, and which he held for ten years, he was also in charge of development work on protection from lightning and from corrosion damage to cables. Dr. Trueblood has been a member and secretary since its organization of the Joint Subcommittee on Development and Research of the Edison Electric Institute and the Bell System. During World War II, Dr. Trueblood did work concerned with field testing of radar systems and the development of radar indicators. Beginning his career in 1903, he became a field officer with the United States Coast and Geodetic Survey, subsequently teaching electrical engineering at the University of Pennsylvania, Philadelphia. He joined the Engineering Department of American Telephone and Telegraph Company in 1917, but left after a few months to engage in research at the United States Naval Experimental Station, New London, Conn. He returned to the Bell System in 1919. Mr. Trueblood served on the following committees: Protective Devices, 1934–37; Transmission and Distribution, 1938–49; Board of Examiners, 1943–49.

William L. Dubilier (A '19, F '25), Technical Director and founder of the Cornell-Dubilier Electric Corporation, South Plainfield, N. J., recently received two high French honors at that country's embassy in New York, N. Y. One was the Honorary Medal of the Association des Ingenieurs-Docteurs de France. The Diploma of the Officer of the Academy and the Order of Academic Palms, presented by decree of the French government, was Mr. Dubilier's second award. The scientist was honored for two services to France, one rendered during World War I, and the other completed just recently. In his later service, he assisted in providing emergency relief for the serious shortage of power in the French nation. Working through the Cornell-Dubilier Electric Corporation, he was responsible for French power companies' obtaining 40,000 kw. He also assisted in building up the country's capacitor industry. Mr. Dubilier's service in World War I was the development, at the request of the government of France, of a submarine detector, which obtained the location, speed, and direction of the target. Holder of over 300 patents, the scientist's most famous contribution to the electrical industry was his development of the mica capacitor, a device almost as important in modern electronics as the radio tube itself. Born in New York, N. Y., July 25, 1888, Mr. Dubilier studied at Cooper Institute and the University of Paris. Chief electrician for the Continental Wireless and Telegraph Company in 1908, he was President and Technical Director of the Commercial Wireless Telegraph and Telephone Company, Seattle, Wash., by 1910. In London, England, in the same year, he organized the Dubilier Condenser Company, Limited. Returning to New York, N. Y., he founded the Dubilier Electric Company in 1913, which firm is now the Cornell-Dubilier Electric Corporation. Author of a number of technical articles, Mr. Dubilier is a member of the Institute of Radio Engineers and the Franklin Institute.

H. E. Dralle (A '41) is now Eastern Engineering and Service Manager, Westinghouse Electric Corporation, New York, N. Y. Formerly Assistant Manager, he replaces **S. L. Henderson** (A '12, M '34), who has retired. Mr. Henderson, a Member for Life, had been with Westinghouse since 1910. Also retired recently is **H. K. Smith** (M '35, F '44), who was Northwestern Engineering and Service Manager at the company's Chicago, Ill., office. Succeeding to Mr. Smith's former position is **D. E. Inman** (A '38, M '45). **M. L. Gardner** (A '40, M '46) fills Mr. Inman's previous post of Engineering Manager at East Pittsburgh, Pa. For the last four years, Mr. Gardner had been Supervisor of Industrial and Central Station Engineering in Westinghouse's, New York, N. Y., Branch. Mr. Henderson has served on the Electrical Machinery, the Technical Program, and the Education Committees. Mr. Inman has been a member of the Industrial Control Committee, and the Publication Committee. Mr. Dralle has belonged to the Land Transportation Committee. Mr. Smith has served on the Membership and Transfer Committees.

J. P. Growdon (A '12, M '20), Chief Hydraulic Engineer, Aluminum Company of America, Pittsburgh, Pa., has been awarded the honorary degree of Doctor of Engineering by the University of Nebraska. A graduate of that institution, he has been with the Aluminum Company of America since 1925, designing and directing construction of most of the large hydroelectric dams built by the company to furnish power for its aluminum plants. Just prior to World War II, his technical assistance helped make possible the construction of the United States Navy's huge underground oil storage project in Hawaii, where 20 great cylindrical vaults were carved out of solid rock, entirely underground. He was awarded the Navy's Certificate of Merit for his contributions to this undertaking. Mr. Growdon is a Member for Life.

William Dubilier

E. J. Thimme (A '27, M '29), until recently Division Superintendent, Passaic Division, Public Service Electric and Gas Company, Newark, N. J., has been named Industrial Relations Manager for the utility. In other company changes, **C. L. Dudley** (A '23, M '29), formerly Division Superintendent, Essex Division, has become Assistant General Superintendent of Distribution; **Oscar Bauhan** (M '40), formerly Assistant Transmission and Substation Engineer, has been designated Transmission and Substation Engineer; and **Theodore Seely** (A '41), until recently Transmission and Substation Engineer, has filled the position of Division Superintendent, Essex Division. Each of the four men began working for the company immediately after leaving college, Mr. Thimme, Mr. Bauhan, and Mr. Seely in 1923, and Mr. Dudley in 1920. Mr. Dudley is a past member of the Electrochemistry and Electrometallurgy Committee.

W. J. Lyman (A '25, F '43) has been appointed Manager, Planning and Development Department, Duquesne Light Company, Pittsburgh, Pa. Previously, he was Engineering Assistant to the Manager of that department. Named as Consultant to Mr. Lyman is **E. A. Hester** (A '18, F '47). Mr. Hester has been with the utility since 1926. From 1941 to 1944, he served with the War Production Board. Mr. Lyman joined Duquesne Light in 1924. He has served on the Membership Committee and the Power Generation Committee. Mr. Hester is a past member of the Protective Devices, the Meetings and Papers, and the Electric Welding Committees.

Tomlinson Fort (A '27, M '35), for six years Manager, Central Station Department, has been made Manager of the Apparatus Sales Department, Westinghouse Electric Corporation, East Pittsburgh, Pa. Named to handle Westinghouse's Industrial Products, are **R. C. Bergvall** (A '24, M '41) and **W. W. Sproul** (A '42). Mr. Sproul, former Sales Manager of the company's Transformer Division at Sharon, Pa., assumes the duties of Sales Manager in East Pittsburgh. Assistant to the Vice-President in Charge of Engineering for the past 11 years, Mr. Bergvall has become Engineering Manager. Mr. Bergvall has served on the Standards Council of the American Standards Association and the Protective Devices, the Standards, and the Nucleonics Committees.

S. G. Hibben (A '34, M '45), of the Westinghouse Electric Corporation, Bloomfield, N. J., has been elected Vice-President of the Illuminating Engineering Society. Other new officers are: **E. M. Strong** (A '26, M '40) of Cornell University, Ithaca, N. Y., Treasurer; **A. H. Manwaring** (A '40, M '46), Philadelphia (Pa.) Electrical and Manufacturing Company, who becomes General Secretary; and **R. L. Biesele, Jr.** (A '45, M '48), of Southern Methodist University, Dallas, Tex., Director. Their duties will begin October 1, 1949. Both Mr. Hibben and Mr. Strong have been active AIEE committee members. Each has served on the Production and Application of Light, Standards, and Technical Program Committees, to name only a few.

D. M. Jones (A '21), Manager, Central Station Engineering Divisions, General Electric Company, Schenectady, N. Y., recently retired after 32 years with the company. He has filled his last post since 1938. Replacing Mr. Jones is **W. J. McLachlan** (A '40, M '45), who formerly was an Assistant Manager in the same department. The new Manager joined General Electric in 1924. Mr. Jones has served on the Technical Program Committee and the Power Generation Committee.

L. M. Robertson (A '27, F '45), Assistant Superintendent, Hydroelectric Production and Transmission Department, Public Service Company of Colorado, Denver, has been elected President of the Colorado Engineering Council. Formerly, he served as Vice-President of the group, which represents 3,000 engineers in the state of Colorado. Vice-President of AIEE, 1945–47, Mr. Robertson has been a member of the following committees: Transmission and Distribution; Rotating Machinery; and Education.

R. A. Millikan (M '22, HM '33), retired executive head of the California Institute of Technology, Pasadena, has received the Presidential Medal of Merit. The award was in recognition of "exceptionally outstanding conduct" in the field of rocket and jet propulsion development. A 1922 Edison Medalist, Dr. Millikan has served on the Electrophysics Committee and the Edison Medal Committee.

E. E. Ellis (A '49), former Engineer-in-Charge of Sales of the Motor and Generator Section, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been named

Manager of that Section. **V. J. Egan** (A '39, M '47) succeeds to Mr. Ellis' previous position. **H. H. Roth** (A '40) has been appointed Engineer-in-Charge of the Large Generator Sales Group. For the last two years, he was Application Engineer in the Generator Group of the Motor and Generator Section.

H. E. Strang (A '28, F '45), until recently Engineering Manager of the Affiliated Manufacturing Companies Department of the General Electric Company has been named Manager of the Apparatus Department's Meter and Instrument Divisions at Lynn, Mass. Mr. Strang began his career with General Electric in 1925. Some of the committees on which he has served are: Protective Devices; Standards, Technical Program; Award of Institute Prizes; and Management.

R. S. Fleshiem (A '26, M '36) has been promoted from Manager of the Electrical Department to Assistant to the Executive Vice-President of the General Machinery Division of the Allis-Chalmers Manufacturing Company, Milwaukee, Wis. **R. M. Casper** (M '40), formerly Manager of the Motor and Generator Section, has assumed Mr. Fleshiem's previous duties. Mr. Fleshiem has been with Allis-Chalmers since 1904, and Mr. Casper, since 1936.

H. F. Dart (A '20, M '26), Office Manager, Electronic Tube Engineering Department, Westinghouse Electric Corporation, Bloomfield, N. J., has been elected Chairman of the New York section of the Institute of Radio Engineers for a term of one year. A member of that society since 1920, he joined the Westinghouse staff in 1922. He served on the AIEE Electronics Committee, 1948–49.

P. D. Wagoner (A '02), Chairman of the Board and Chief Executive of the Underwood Corporation, New York, N. Y., has received an honorary Doctor of Engineering degree from his alma mater, the Stevens Institute of Technology, in Hoboken, N. J. He is an 1896 mechanical engineering graduate. Associated with the Underwood Corporation and its predecessor companies for over 30 years, he is a Member for Life.

H. H. Cochrane (M '43), Chief Engineer, Montana Power Company, Butte, has retired after 50 years of service. **A. C. Pratt** (A '03, M '12), formerly Assistant Chief Engineer, retired at the same time. Mr. Pratt is a Member for Life. Both have been retained by the company as full-time consultants. Recent appointments made by Montana Power are: **C. H. Kirk** (A '43) to Superintendent of Transmission and Distribution; and **H. K. Dickinson** (A '44) to Electrical Engineer.

W. K. Scott (A '42, M '44), until recently Assistant Superintendent of Construction, Columbia Steel Company, Pittsburg, Calif., has been designated Electrical Engineer and will work in Oakland, Calif. He has been identified with Columbia for 25 years.

W. M. McKie (A '41, M '47) now is working in the Toronto district office of the Canadian General Electric Company, Limited, Toronto, Ontario, where he is responsible for the sales engineering of heavy industrial equipment in the area between North Bay and Saulte Ste. Marie. Formerly, he was Manager of the Electronic and Rectifier Section at the company's head office.

I. W. Borda (M '39) and **W. R. Van Steenburgh** (A '21) have been appointed Vice-Presidents of the Okonite Company, Passaic, N. J. With Okonite since 1924, Mr. Borda continues as Manager of the Pacific Coast District in San Francisco, Calif. Mr. Van Steenburgh, who joined the firm in 1917, retains his duties as Manager of the North-East Sales District in New York, N. Y.

W. W. Ege (A '23, M '32), previously General Manager of Sales, has been named to the newly created position of Vice-President, Sales, with the Copperweld Steel Company, Glassport, Pa. Other promotions are **F. E. Leib** (M '44) to Assistant to Vice-President, Sales, and **P. A. Terrell** (M '30) to Assistant Vice-President. Before, Mr. Leib was Assistant General Manager of Sales, and Mr. Terrell was Assistant to the Executive Vice-President.

A. S. Albright (M '37, F '43), Controller of the Detroit (Mich.) Edison Company since 1943, has been elected Treasurer of the utility. He has been with the firm since 1912, when he was employed as an engineer in the statistical department. Mr. Albright has served on the Instruments and Measurements and the Basic Sciences Committees.

F. M. Bilhimer (M '41) engineer with the Equitable Life Assurance Society, New York, N. Y., has been elected President of the New York Chapter of the National Society of Professional Engineers. Also, **B. E. Anderson** (M '35, F '45), electrical engineer at Ebasco Services, Inc., New York, N. Y., was voted Vice-President.

F. K. McCune (A '33, M '43), former Assistant to the General Manager, Apparatus Department, has been appointed Assistant General Manager of the Nucleonics Department, General Electric Company, Schenectady, N. Y. With General Electric since 1928, Mr. McCune served on the Transfers Committee, 1946–48.

C. W. La Pierre (A '28, M '43), formerly Vice-President in Charge of Engineering, American Machinery and Foundry Company, New York, N. Y., is now assistant Manager of the Aircraft Gas Turbine Divisions, General Electric Company, Lynn, Mass. Mr. La Pierre served on the Membership Committee, 1945–48.

H. A. Glover (A '39), formerly Assistant Sales Manager, has been designated Sales Administration Manager with the S and C Electric Company, Chicago, Ill. Prior to joining the firm in 1946 as Sales Department Supervisor, he had worked for the I-T-E Circuit Breaker Company, Philadelphia, Pa.

W. L. Bird (A '03, F '20), Vice-President, Kaministiquia Power Company, Limited, Fort William, Ontario, Canada, has retired. He has been in the electrical industry 54 years. A Member for Life of the Institute, he served on the Power Stations Committee, 1917–19.

J. K. Hodnette (A '25, F '42), Vice-President and Head of the Transformer Division, Westinghouse Electric Corporation, Sharon, Pa., has become General Manager of Industrial Products with headquarters at Pittsburgh, Pa. Mr. Hodnette served on the Electrical Machinery Committee.

W. R. Coley (A '19, M '25), Vice-President in Charge of Production since 1944 of the Leeds and Northrup Company, Philadelphia, Pa., has retired. He has been with the firm since 1906, when he was employed as an instrument maker in the galvanometer section of the laboratory.

L. E. Record (A '31), for six years supervisor of the Tube Development Laboratory, has been named Supervisor of the Development and Testing Laboratories for the Tube Division, General Electric Company, Schenectady, N. Y.

Edward Allen (A '40, M '47) is the new Midwestern Editor of *Electrical World*. His headquarters are in Chicago, Ill. Formerly, he had been General Service Engineer for the Electric Power Board of Chattanooga, Tenn.

R. R. Jackson (A '45) is in charge of the Edmonton office of F. D. Bolton, Limited, in Edmonton, Alberta, Canada. Formerly, Mr. Jackson was in the employ of the Canadian General Electric Company, Winnipeg, Manitoba.

W. H. Stueve (M '43), Executive Assistant, Oklahoma Gas and Electric Company, Oklahoma City, has been initiated into the Oklahoma University Chapter of Tau Beta Pi for his outstanding achievements in the engineering field.

S. W. Booth (M '45), formerly Associate Chief, has been made Chief of the Engineering Department of the Naval Ordnance Laboratory at White Oak, Md. Mr. Booth joined the laboratory in 1941.

L. R. Crane (A '41), formerly Switchgear Specialist, has been made Manager of Switchgear Sales, A. B. Chance Company, Centralia, Mo.

H. L. Scott (A '49), owner of the Scott Electric Company, Corpus Christi, Tex., has been appointed Chairman of the Business Promotion Committee of the National Electrical Contractors Association.

W. F. Rauber (M '45) is now Manager of Sales for the Switchgear Division, Apparatus Department, General Electric Company, Philadelphia, Pa.

J. T. Ward (A '44) has been appointed vice-president in charge of engineering and operations at the Boston (Mass.) Edison Company Joining the company in 1941, as head of the radio department, he became a vice-president of the Boston utility one year later. Previously, Ward had been affiliated with the Massachusetts Institute of Technology, Cambridge, Mass., and was director of the research laboratory for the M. W. Kellog Company, New York, N. Y.

G. J. Taylor (M '44) of Day-Brite Lighting Inc., New York, N. Y., has been named eastern sales manager of that company. He will be in charge of a territory covered by the New England states, New York State, Pennsylvania, New Jersey, and Washington, D. C. Mr. Taylor joined Day-Brite in 1947. Previously, he had worked for the Cooper-Hewitt Company and General Electric Company.

S. A. Smith (A '24, M '31) has been elected vice-president in charge of research and development at the General Cable Corporation, New York, N. Y. At the same time, **A. D. Pettee** (A '20 F '45) was made vice-president in charge of product engineering. Mr. Pettee now is serving on the Insulated Conductors Committee.

G. M. Woods (M '43), has been appointed manager of the transportation section, industry engineering department, Westinghouse Electric Corporation, East Pittsburgh, Pa. He has been doing transportation engineering work since 1911 when he joined the company.

Neil Metz (A '39) is now transmission engineer in the operations department of the Florida Power and Light Company, Miami. In the same department, **O. T. Ayers** (M '47) has been appointed distribution engineer and **R. A. Goodburn** (A '37) system engineer.

R. E. Worstell (M '46) has been appointed manager of quantity consumer sales, lamp department, General Electric Company, Cleveland, Ohio. Formerly, he was supervisory engineer, Atlantic sales district, in General Electric's New York, N. Y., offices. He has been with the company since 1925.

H. A. Howard (A '45), formerly manager, Brantford Township Hydro-Electric Commission, Brantford, Ontario, Canada, is now superintendent of the Thorold Public Utilities Commission.

E. C. Easter (A '46) is now sales manager, Alabama Power Company, Birmingham. Identified with the utility since 1924, he became chief agricultural engineer three years later, and manager of the rural and towns division in 1933.

A. R. Nelson (A '22, M '29), formerly assistant general superintendent, electrical distribution, Public Service Electric and Gas Company, Newark, N. J., has been named general superintendent. He has been with the company since 1920.

R. A. Merrill (A '47) head of the University of Chattanooga (Tenn.) Engineering Department has been elected president of the newly organized Tennessee Society of Professional Engineers.

J. H. Goss (A' 35, M '43), until recently assistant manager of engineering, control division, General Electric Company, Schenectady, N. Y., has been promoted to manager of engineering. He has been with General Electric since 1931, when he joined the company as a student engineer.

W. G. Albright (A '43), until recently an instructor, has been promoted to an assistant professorship in the electrical engineering department at the University of Illinois, Urbana.

K. W. Johansson (A '11, M '28), formerly connected with the Aluminum Company of America and the Westinghouse Corporation, is now local manager of the Arvada Electric Company, Arvada, Colo. Johannson is a Member for Life of the Institute.

OBITUARY • • • •

George Hart Morse (F '22), consulting engineer, Arlington, Va., died June 1, 1949. A native of St. Paul, Minn., born May 23, 1871, he graduated from the University of Minnesota in 1893 and received an advance degree in electrical engineering from the same university in 1911. Beginning his career in 1893 as a special apprentice with the General Electric Company, Schenectady, N. Y., he subsequently was associated with the Wagner Electrical Manufacturing Company, St. Louis, Mo., and the Benton Harbor Electric Light Railway and Power Company, St. Joseph, Mo. In 1899, he became an instructor in electrical engineering at the University of Nebraska, Lincoln. Three years later, he was designated Professor in and head of the electrical engineering department. After 13 years at the university, he joined the Mutual Electric and Machine Company, Detroit, Mich., as consulting engineer. From 1918 to 1921, he was power specialist and appraisal engineer with the United States Shipping Board Emergency Fleet Corporation. During the interval, 1922–31, he was employed by the Commonwealth of Pennsylvania, for which he did work on the Giant Power Survey, Public Service Commission, and Department of Welfare. Subsequently, he was chief engineer with the New York Power Authority, and, in 1933, he was Chief of the Distribution Cost Survey, conducted by the Federal Power Commission in fulfillment of a Senate resolution. This was the last post he held prior to his retirement from government service. He was the author of articles in the Giant Power Survey published by the Commonwealth of Pennsylvania, and the patentee of electric switches, calculating machines, and television receiving apparatus. He was the codiscoverer of the Morse-Cushman Effect, namely, rectification of an alternating current by means of one arc drawn between three carbons in a magnetic field.

Preston Strong Millar (A '03, M '13), President and Director, Electrical Testing Laboratories, Inc., New York, N. Y., died June 17, 1949. He had been associated with the laboratories and its predecessor for 52 years. Born in Andover, N. J., on March 9, 1880, he joined the Lamp Testing Bureau of the Association of Edison Illuminating Companies at Harrison, N. J., in 1897. Two years later, he became Assistant Manager of the company. In 1900, the Lamp Testing Bureau became the Electrical Testing Laboratories, of which firm, Mr. Millar was designated General Manager in 1914. He was named President in 1929. From 1919 to 1942, he was Secretary of the Association of Edison Illuminating Companies. Co-inventor of the Sharp-Millar photometer, he was the author of numerous technical articles, and contributed to the section on illumination in the Standard Handbook for Electrical Engineers. Mr. Millar was one of the founders of the Illuminating Engineering Society and was its president in 1913. In 1945, he received the society's Gold Medal for his services to that organization and for his contributions to the science of lighting. Other groups in which Mr. Millar was active were: the United States National Committee of the International Commission on Illumination (President, 1936–48); the American Council of Commercial Laboratories (President, 1937–39); and the New York Electrical Society, Inc. (President, 1943–44). He was a fellow of the American Physical Society, the American Association for the Advancement of Science, and the Illuminating Engineering Society, and was a member of the American Optical Society, the American Society for Testing Materials, and the Association of Consulting Chemists and Chemical Engineers. During World War II, Mr. Millar was lighting adviser to the Office of Civilian Protection of Westchester County. He served on the Electrophysics Committee, 1917–18, the Production and Application of Light Committee, 1923–46 (Chairman 1925–28), and the Meetings and Papers Committee, 1925–28. He was a Member for Life.

Norman Leslie Rea (A '02), former Engineering Consultant, Service Engineering Divisions, General Electric Company, Schenectady, N. Y., died May 10, 1949. He was with the company for over 45 years. Born April 11, 1879 in East Beekmantown, N. Y., he received a Bachelor of Science degree in electrical engineering from the Clarckson School of Technology in 1901. Joining General Electric shortly thereafter, he worked in the Testing Department and, later, the Construction Department. Subsequently, he became Supervising Engineer of the latter department. Named Supervising Engineer of the Contract Service Department in 1925, he was designated Superintendent of Electrical Installation in the Service Engineering Divisions eight years afterward. In this post, he directed installations of General Electric apparatus throughout the world. Some American projects on which he worked were the Bonneville Dam, Boulder Dam, and water-power stations of the Tennessee Valley Administration. Abroad, he helped to install generating equipment at the following sites: Santos, Brazil; LaGuaira, Venezuela; and Dnieprostroi, Russia. In addition, he worked on the Rione project in Uruguay and various installations in India. Mr. Rea was appointed Engineering Consultant in 1945, and he retired from General Electric two years later. He was a Member for Life.

Raymond Robert Stoddard (A '38), lawyer and engineer, who had served the Philadelphia (Pa.) Electric Company from 1926 to 1943, died June 16, 1949. For the last five years, he was Industrial Power Engineer for the Brockton Gas Light Company, Concord Electric Company, Exeter and Hampton Electric Company, Pike County Light and Power Company, Rockland Electric Company, Rockland Light and Power Company, Fitchburg Gas and Electric Company, and Springfield Gas Light Company, all in New England and New York. His office was in Boston, Mass. Born December 9, 1900, in Lynn, Mass., Mr. Stoddard had bachelor's and master's degrees in electrical engineering from the Massachusetts Institute of Technology, as well as a Doctor of Laws degree from Temple University Law School. He was a member of the bar, admitted to practice before the United States District Court and Court of Appeals in Washington. Between his Philadelphia and Boston posts, Mr. Stoddard was with the Sperry Gyroscope Company, Garden City, L. I. Prior to working for the Philadelphia Electric Company, he had been a power salesman with Binghamton (N. Y.) Light, Heat and Power Company from 1925 to 1926.

Grover C. Meyer (M '44) Industrial Engineer with the Kansas City (Mo.) Power and Light Company for 32 years died June 2, 1949. A native of Missouri, he was born in Higginsville on September 9, 1892. Graduated in 1917 from Finlay Engineering College, he began his career with the Kansas City Power and Light Company shortly thereafter. During his first four years with the utility, he was in charge of replacing 25-cycle with 60-cycle equipment in flour mills, grain elevators, and feed mills. Later, he did work in the fields of power sales, power cost analysis, and power applications. From time to time, he also did consulting engineerwork for such firms as the Horner Wyatt Engineering Company of Kansas City and the Cereal Engineering Company of Minneapolis, Minn.

Joseph Henry Yarnall (M '19, F '46), formerly Superintendent of Power for the Boston (Mass.) Elevated Railway, now the Metropolitan Transit Authority, died June 5, 1949. He had been with the company since 1906, which he joined after one year with the General Electric Company at Lynn, Mass., as a student apprentice. After three years of service with the transit company he was designated Assistant Engineer in the Electrical Engineering Department. In 1923, he was promoted to Power Engineer in the company's Power Engineering Department. He became Superintendent of Power in 1943. Three years later, he retired. A native of Sunbury, Pa., born January 6, 1884, he received a Bachelor of Science degree from Pennsylvania State College in 1905 and an electrical engineering degree from the same institution in 1914.

Fred Alan Fish (A '00, F '13), Professor of Electrical Engineering, Iowa State College, Ames, died May 20, 1949. He had been teaching at the college since 1905, when he was appointed Associate Professor of Physics and Electrical Engineering. Named Professor of Electrical Engineering and Head of the department in 1907, he relinquished the duties of the latter post in 1930, but remained as Professor. Prior to joining the staff of Iowa State College, Professor Fish served for four years as Assistant Professor of Electrical Engineering at Ohio State University, Columbus. From 1898 to 1900, he had been an instructor at Ohio State, and, in the year that followed, he taught at the University of Wisconsin, Madison. An alumnus of Ohio State University, he was born February 21, 1875 in Milan, Ohio. Professor Fish was identified with the following organizations: the National Electric Light Association (now the Edison Electric Institute), the American Society of Engineering Education; Sigma Xi; Tau Beta Pi; Eta Kappa Nu; and Phi Kappa Phi. He was a Member for Life.

MEMBERSHIP

Recommended for Transfer

The board of examiners at its meeting of July 21, 1949 recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Alexander, E. H., mgr., commercial engg. div., General Elec. Co., Schenectady, N. Y.
Clark, L. W., supt. underground lines dept., The Detroit Edison Co., Detroit, Mich.
Dibble, B., consulting engr., 120 E. Palm Ave., Redlands, Calif.
Foulkrod, R., plant extension engr., Michigan Bell Tel. Co., Detroit, Mich.
Hodtum, J. B., central station engr., Allis-Chalmers Mfgr. Co., Pittsburgh, Pa.
Holland, W. A., elec. engg. lecturer, Drexel Inst. of Tech., Phila., Pa.
Landis, G. H., chief engr., Central Hudson Gas & Elec. Corp., Poughkeepsie, N. Y.
Lauder, A. H., asst. mgr. of engg., large motor & generator div., General Elec. Co., Schenectady, N. Y.
Mathewson, H. G., building & equipment engr., Texas area, Southwestern Bell Tel. Co., Dallas, Tex.
Miner, J. D., Jr., mgr., aviation engg. dept., Westinghouse Elec. Corp., Lima, Ohio
Montgomery, T. B., engr. in-chg., control engg., Allis-Chalmers Mfgr. Co., Milwaukee, Wis.
Moulton, J. S., vice pres. & exec. engr., Pacific Gas & Elec. Co., San Francisco, Calif.
Schmitt, G. E., asst. genl. mgr. & chief engr., Lower Colorado River Authority, Austin, Tex.
Sherwin, J. L., chief elec. engr., Arthur G. McKee & Co., Cleveland, Ohio
Stivender, E. H., elec. engr., Allis-Chalmers Mfgr. Co., Milwaukee, Wis.
Wiltse, S. B., prof. of elec. engg.; chairman, coop. & extension education, Rensselaer Poly. Inst., Troy, N. Y.

16 to grade of Fellow

To Grade of Member

Ashley, D. P., elec. engr., Long Island Lighting Co., Mineola, N. Y.
Balch, L. C., sales engr., Kingsport Elec. Co., Inc., Kingsport, Tenn.
Beem, F. A., engr., Illinois Bell Tel. Co., Chicago, Ill.
Bissel, E. E., Jr., electronic engr., Naval Research Laboratory, Washington, D. C.
Brancke, C. A., control engr., General Elec. Co., Erie, Pa.
Bredenberg, A., Jr., design & application engr., General Elec. Co., Erie, Pa.
Bretz, G. W., elec. engr., Air Products, Inc., Emmaus, Pa.
Cattolica, J. L., asst. engr., Pacific Gas & Elec. Co., San Francisco, Calif.
Christie, J., elec. engr., Messrs. A. Reyrolle & Co., Ltd., Hebburn-on-Tyne, England
Clark, E. C., application engr., General Elec. Co., Schenectady, N. Y.
Cobb, L. M., supervisor, elec. system analysis group, The Glenn L. Martin Co., Baltimore, Md.
Cooper, T. R., chief, elec. & mech. sections, Public Service Comm. of W. Va., Charleston, W. Va.
Dukes, W. W., Jr., vice pres., Applied Engg. Co., Inc., Orangeburg, S. C.
Eschmann, W. G., project liaison engr., The Glenn L. Martin Co., Baltimore, Md.
Ewing, P. B., foreign wire relations engr., Indiana Bell Tel. Co., Indianapolis, Ind.
Folks, J. C., service engr., General Elec. Co., Los Angeles, Calif.
Fritsche, W. O., elec. engr., United Illuminating Co., New Haven, Conn.
Fritz, J. R., elec. engr., Gilbert Associates, Inc., Reading, Pa.
Fuegel, E. F., development engr., General Elec. Co., Pittsfield, Mass.
Gaskin, G. C., elec. engr., J. E. Sirrine Co., Greenville, S. C.
Gordon, K. H., asst. elec. engr., The Pennsylvania R. R., Philadelphia, Pa.
Green, J. A., elec. engr., Collins Radio Co., Cedar Rapids, Ia.
Gregory, L. W., design engr., Westinghouse Elec. Corp., Baltimore, Md.
Hastings, H. R., engr., product or design, A. C. Spark Plug Div., GMC., Flint, Mich.
Hoffmann, A. H., electrical design engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Hutchison, W. M., transportation application engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Jenkins, R. W., senior engr., Consolidated Gas Elec. Light & Pr. Co. of Baltimore, Md.
Jensen, H. A., general foreman, electrical maintenance dept., Nash Kelvinator Corp., Kenosha, Wis.
Johansson, A. V., control requisition engr., General Elec. Co., Erie, Pa.
Kaufman, R. B., developmental engr., General Elec. Co., Pittsfield, Mass.
Linsday, E. A., elec. engr., General Elec. Co., Cleveland, Ohio
Longwell, R. R., engg. & service supervisor, Westinghouse Elec. Corp., Baltimore, Md.
Lyon, W. D., engr., toll plans & estimates, Illinois Bell Tel. Co., Chicago, Ill.
MacLane, G. L., Jr., asst. mgr., engg. labs. & stds., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Margrave, H. E., chief system operator, Kansas Gas & Elec. Co., Wichita, Kans.
Mattison, G. G., asst. supt., elec. maint. & const., Duke Power Co., Charlotte, N. C.
McClure, R. F., system distribution engr., Southwestern Public Service Co., Amarillo, Tex.
McDonnell, J. A., dev. engr., General Elec. Co., West Lynn, Mass.
Misegades, E. L., engg. air conditioning dept., General Elec. Co., Bloomfield, N. J.
Mitch, J. E., engr., The Arnold Engg. Co., Marengo, Ill.
Nelson, J. S., design engr., General Elec. Co., West Lynn, Mass.
Peter, B. L., asst. engr., Pacific Gas & Elec. Co., San Francisco, Calif.
Plunkert, J. F., electronics engr., P-6, Naval Air Test Center, Patuxent River, Md.
Pool, R. P., chief engr. & project mgr., rayon plant, F. V. Llolleo, San Antonio, Chile, S. A.
Quill, J. S., application engr., General Elec. Co., Schenectady, N. Y.
Ringe, G. T., Jr., headquarters avia. repr., Westinghouse Elec. Corp., Los Angeles, Calif.
Rosenquist, R. T., induction motor section engr., Elliott Co., Ridgway, Pa.
Sanderson, H. A., sales engr., Northern States Power Co., Minneapolis, Minn.
Schaeffer, G. H., Jr., elec. engr., Carpenter Steel Co., Reading, Pa.
Schlawin, R. G., designing engr., power trans. engg. div., General Elec. Co., Pittsfield, Mass.
Schlitt, W. J., Jr., engr., Columbus & Southern Ohio Elec. Co., Columbus, Ohio
Sherman, H., chief, systems analysis unit, Watson Labs, AMC, Red Bank, N. J.
Shores, R. B., section engr., development section, General Elec. Co., Phila., Pa.
Smith, J. P., application engr., ind. engg. divs., General Elec. Co., Schenectady, N. Y.
Speight, J. W., testing engr., section head, Hydro-Elec. Power Comm. Labs., Toronto, Ont., Can.
Spencer, J. H., engr., General Elec. Co., Pittsfield, Mass.
Stork, C. L., asst. elec. engr., Eastman Kodak Co., Rochester, N. Y.
Sutherland, R., engr., General Elec. Co., Pittsfield, Mass.
Swinney, J. G. C., Jr., senior engr., International Standard Elec. Corp., New York, N. Y.
Taborsky, S., elec. engr., Glenn L. Martin Co., Baltimore, Md.
Tarpley, H. I., elec. engg. prof., Pennsylvania State College, State College, Pa.
Warshaw, J., chief product engr., International Resistance Co., Phila., Pa.
Whitesell, R. O., consulting engr., Engineering Products, Indianapolis, Ind.
Wilson, M. E., asst. supervisor, elec. system protec. div., Consolidated Gas Elec. Light & Pr. Co. of Baltimore, Md.
Wright, H. E., field application engr., I-T-E Circuit Breaker Co., Boston, Mass.

65 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership have been received during the month ending August 5, 1949, from the persons listed below. Any member objecting to the election of any of these candidates should so inform the secretary before September 25, 1949, or November 25, 1949, if the applicant resides outside of the United States, Canada, or Mexico. All but a small number of the applications for Associate membership listed below have been received from Student members whose term of such affiliation will not expire until April 30, 1950; action upon such applications will therefore be deferred until that time in practically all cases.

To Grade of Fellow

Brazier, L. G., British Insulated Callender's Cables, Ltd., London, England
1 to grade of Fellow

To Grade of Member

Bewley, J. O., Jr., General Elec. Co., Charleston, W. Va.
Sundararaman, R., The Crompton Eng. Co. (Madras) Ltd., Madras, South India
Conners, M. J., Air Reduction Co., New York, N. Y.
Donahue, R. A., Western Elec. Co., Kearny, N. J.
Lear, W. E., Univ. of Florida, Gainesville, Fla.
Wellan, W. H., North Dakota State School of Science, Wahpeton, N. Dak.
Smith, H. W., Lenkurt Elec. Co., Inc., San Carlos, Calif.
Ackroyd, R. T., Ministry of Supply, Warrington, England
Coutts, C. A., Northern States Power Co., Minneapolis, Minn.
Eschholz, P. A., The Hartford Elec. Light Co., Hartford, Conn.
Hanft, H., 711 New Jersey Ave., Brooklyn, N. Y.
Hawk, R. A., Northern Indiana Public Service Co., Goshen, Ind.
Hitzel, W. C., N. Y. State Elec. & Gas Corp., Lockport, N. Y.
Johannsen, E. A. R., Parsons Aerojet Co., Los Angeles, Calif.
McDonough, J. B., General Elec. Co., San Francisco, Calif.
Morrin, T. H., Stanford Research Inst., Stanford, Calif.
Nicholas, J. E., Pennsylvania State College, State College, Pa.
Roach, O. R., 332 S. Michigan Ave., Chicago, Ill.
Sands, G., Naval Headquarters, Ottawa, Ont., Canada
Scott, A. H., General Elec. Co., Pittsfield, Mass.
Thompson, G. E., Kaiser Co., Inc., Fontana, Calif.

21 to grade of Member

To Grade of Associate

United States, Canada, and Mexico

1. North Eastern

Albaugh, S. W., West Main Rd., Fredonia, N. Y.
Andrew, R. T., Raytheon Mfg. Co., Waltham, Mass.
Angelo, J., General Elec. Co., Schenectady, N. Y.
Appleton, W. B., 71 Hillbert Ave., Brockton, Mass.
Aubrey, A. M., 165 Centre St., Middleboro, Mass.
Austin, E. N., 29 Worcester St., Belmont, Mass.
Bassett, J. D., 35 Haskins St., Providence, R. I.
Berger, M. A., 929 Blue Hill Ave., Dorchester, Mass.
Besser, R. W., 62 Homewood Ave., No. Providence, R. I.
Bunnecke, R. J., 2005 Hoover Rd., Schenectady, N. Y.
Burk, M. K., General Elec. Co., Schenectady, N. Y.
Busharis, J. G., 35 Zumora St., Jamaica Plain, Mass.
Buss, H. W., Rochester Gas & Elec. Corp., Rochester, N. Y.
Caddell, R. C., Jr., 3 Wood St., Fairhaven, Mass.
Campbell, J. M., 289 Angell St., Providence, R. I.
Carson, J. R., 501 Essex St., Bangor, Me.
Carvill, A. L., (re-election) 40 Federal St., W. Lynn, Mass.
Chamberlain, W. E., Jr., 116 Fairview St., Providence, R. I.
Charow, W. J., 1 Belchertown St., Three Rivers, Mass.
Clark, N. F., 3 Norton St., West Lynn, Mass.
Clarke, W. V., 78 Mendon St., Uxbridge, Mass.
Colarusso, J. E., 572 Admiral St., Providence, R. I.
Cooper, S., 136 Fellsway West, Medford, Mass.
Cowen, T. S., N. Y. State Elec. & Gas Corp., Binghamton, N. Y.
Degan, L. J., General Elec. Co., Pittsfield, Mass.
Deuring, W. G., Jr., General Elec. Co., Pittsfield, Mass.
Dickson, A. W., Mass. Inst. of Tech., Cambridge, Mass.
Donegan, E. P., Jr., 862 Washington St., Dorchester, Mass.
Dulong, P. R., 28 Trowbridge Rd., Worcester, Mass.
Durfee, L., Jr., 431-B Elmgrove Ave., Providence, R. I.
Emerson, W. F., R.F.D. #2, Pittsfield, N. H.
Fernandez, R., (Student), Rensselaer Polytechnic Inst., Troy, N. Y.
Ferrante, W. R., 198 Vinton St., Providence, R. I.
Fitzgerald, W. J., Jr., 584 Elm St., New Haven, Conn.
Foss, H. W., 47 Smith St., Marblehead, Mass.
Gates, T. E., Box 541, White River Junction, Vt.
Georgalos, J. E., Boston Edison Co., Boston, Mass.
Gilroy, R. B., 52 Adams Pl., So Weymouth, Mass.
Glasberg, D., 374 Lloyd Ave., Providence, R. I.
Gregory, J. G., 153 Wilbraham Road, Springfield, Mass.
Hale, J. I., Jr., U. S. Naval Shipyard, Portsmouth, N. H.
Haley, J. T., 33 Fourth St., Doven, N. H.
Hatch, D. E., 68 Green St., Bath, Me.
Hayden, H. P., Link Aviation, Inc., Binghamton, N. Y.
Healy, H. G., 285 Pleasant St., Winthrop, Mass.
Henshaw, W. H., Jr., 141 Four Mile Rd., West Hartford, Conn.
Hoag, J. W., Jr., 286 Riverside Ave., Burlington, Vt.
Holmes, R. W., Johnson, Vt.
Hope, B. C., General Elec. Co., Pittsfield, Mass.
Hossfield, G. L., Jr., New England Elec. System, Boston, Mass.
Hurlbert, A. W., 9 Banks St., Cambridge, Mass.
Ignaszewski, C. J., Jr., Erving, Mass.
Jankowski, B., 81 Washington St., Hornell, N. Y.
Johnson, J. K., R.D.#1, Schaghticoke, N. Y.
Kennedy, H. J., 263 Mt. Pleasant Ave., Providence, R. I.
Klein, J. J., 205 Lake View Ave., Cambridge, Mass.
Kogut, J., 108 Pharis St., Syracuse, N. Y.
Komar, M., 131 Boyden St., Woonsocket, R. I.
Krummel, W. M., General Elec. Co., Syracuse, N. Y.
Letourneau, A. L., 59 Prospect St., Ludlow, Mass.
Lilly, J. C., 108 Vine St., Pautucket, R. I.
Lovoi, J. W., Harvard Univ., Cambridge, Mass.
Mahdesyan, M., 123 Japonica St., Pawtucket, R. I.
Mann, W. B., 25 Murray St., Portland, Me.
McFarland, V. E., 81—4th St., Bangor, Me.
McIver, N. E., 202 Milburn St., Rochester, N. Y.
Morey, E. D., Sharon, Conn.
Morisy, P. J., I. B. M. Corp., Endicott, N. Y.
Neubauer, R. L., General Elec. Co., Schenectady, N. Y.
Otto, E. G. (re-election), Hill, N. H.
Paczkowski, H., 13 Carlton St., Salem, Mass.
Paolella, A., 89 Superior St., Providence, R. I.
Parker, R. S., 905 Hall St., Manchester, N. H.
Pechulis, L. T., 153 N. Main St., Uxbridge, Mass.
Pezza, J., 64 A Street, Cranston, R. I.
Prasad, T. L. N. (Student) Harvard Univ., Cambridge, Mass.
Sargent, T. C., Sylvania Elec. Products Inc., Salem, Mass.
Schiffman, M., General Elec. Co., Syracuse, N. Y.
Smith, H. A., Jr., General Railway Signal Co., Rochester, N. Y.
Smith, T. P., (Student), Tufts College, Medford, Mass.
Steves, J. W., 28 Bradbury St., Old Town, Me.
Szepatowski, T. J., 432 River St., Woonsocket, R. I.
Thomas, C. W., 130 Dexterdale Rd., Providence, R. I.
Travers, P., Servomechanisms Lab., Cambridge, Mass.
Wambsganss, B. A., Kingfield, Me.
Weston, W. J., The Connecticut Power Co., New London, Conn.
Weygand, A. D., 3059 Pawtucket Ave., Riverside, R. I.
Willard, C. H., 49 Broad St., Wethersfield, Conn.
Wise, D. O., Jr., 131 Elizabeth St., Hartford, Conn.
Yirrell, F., 11 Whittier St., Winthrop, Mass.

2. Middle Eastern

Aaron, M. R., Franklin Inst. Research Lab., Philadelphia, Pa.
Abbott, W. H., Jr., General Elec. Co., Erie, Pa.
Anders, R. E., 3072 W. 105th St., Up, Cleveland, Ohio
Aydelotte, R. R., 26 Belmont Ave., Wilmington, Del.
Bartholomew, W. J., Jr., Pennsylvania Power & Light Co., Allentown, Pa.
Batcho, J. M., 716 North 4th St., Toronto, Ohio
Beery, W. G., Army Security Agency, Washington, D. C.
Boehler, D. W., Affiliated Gas Equip. Inc., Cleveland, Ohio
Bogner, P. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Bright, D. W., Mine Safety Appliance Co., Pittsburgh, Pa.
Camp, T. B., Jr., Philadelphia Naval Base Shipyard, Philadelphia, Pa.
Carden, G. H., Allis-Chalmers Mfg. Co., Baltimore, Md.
Carr, T. J., R.D.#2, Box 268, Allison Park, Pa.
Catlin, R. C., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Cavolaski, E. C., Pennsylvania Power & Light Co., Pottsville, Pa.
Chackan, N., Jr., 413 Boyd Street, Turtle Creek, Pa.
Church, M. E., R.F.D. #2, Uniontown, Ohio
Cliffe, W. W., Bailey Meter Co. Ltd., E. Cleveland, Ohio
Comerford, W. T., Westinghouse Elec. Corp., Pittsburgh, Pa.
Council, H. A., Taft Trailer #32, Ada, Ohio
Craft, R. F., R.D. 2, Punxsutawney, Pa.
Dickerson, J. E., 3015 Royston Ave., Baltimore, Md.
Diek, H. A., Jr., Philadelphia Naval Shipyard, Philadelphia, Pa.
Dorn, T. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Dow, E. C., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Dudley, H. L., U. S. Navy Communications Station, Washington, D. C.
Dye, J. E., Naval Ordnance Lab., White Oak, Md.
Eavenson, C., C & P Telephone Co., Clarksburg, W. Va.
Farley, P. T., 2 Cable St., Athens, Ohio
Feibelman, L., 342 Forest Ave., Cincinnati, Ohio
Ferguson, R. W., U.S. Naval Air Development Station, Johnsville, Pa.
Fitti, N. S., Jr., Naval Air Development Station, Johnsville, Pa.
Flanigan, J. M., (Student), Univ. of Pittsburgh, Pittsburgh, Pa.
Foster, J. J., 5103 Race St., Philadelphia, Pa.
Fowles, J. D., D. C. Oviatt Co., Cleveland, Ohio
Frencho, J. L., Naval Air Development Station, Johnsville, Pa.
Gallagher, J. S., 36 S. 5th St., Easton, Pa.
Gilcrest, D. E., R.D. #1, Hartville, Ohio
Goldich, N. H., 159 Bala Ave., Bala-Cynwyd, Pa.
Good, L. H., RCA Victor Div., Camden, N. J.
Gotthilf, E. G., P. O. Box 175, Hopewell, N. J.
Graham, J. D., R.D. #1, Turtle Creek, Pa.
Gramelspacher, A. C., Ohio Univ., 21 B, Veterans Village, Athens, Ohio
Gregory, W. R., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Guba, R. A., The Chas. E. Tull Co., Philadelphia, Pa.
Gynn, C. B., Jr., 16919 Lake Ave., Lakewood, Ohio
Haber Atroh, W. C., J & L Steel Corp., Pittsburgh, Pa.
Hanousek, H. W., 3541 Pennington Rd., Shaker Hts. Ohio
Harding, J. H., Westhinghouse Elec. Corp., Pittsburgh, Pa.
Hatch, V. R., American Tel. & Tel. Co., Washington, D. C.
Heins, L. S., United Engineers & Constr. Inc., Philadelphia, Pa.
Hendricks, A. P., United Engrs. & Constructors, Inc., Philadelphia, Pa.
Hessemer, P. B., 606 Evesham Ave., Baltimore, Md.
Hill, E. R., Jeffrey Dewitt Insulator Corp., Kenova, W. Va.
Hines, J. N., Ohio State Univ. Research Foundation, Columbus, Ohio
Hinsey, R. C., Pennsylvania Railroad Co., Saltsburg, Pa.
Hitt, R. E., Rural Electrification Admin., Washington, D. C.
Holder, L. C., Westinghouse Elec. Corp., Pittsburgh, Pa.
Hooper, C. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Hopkins, J. H., 121 Carol St., New Cumberland, Pa.
Jones, H. C., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Kashmar, C. M., 1826 Constitution Ave., Chester, Pa.
Kephart, D. C., Inst. for Cooper. Research, Baltimore, Md.
Kniskern, P. N., 507 Riverview Rd., Swarthmore, Pa.
Knudsen, R. F., 511 Locust Ave., Westmont, N. J.
Kraus, M. H., 5707 Stuart Ave., Baltimore, Md.
Kravitz, S., 3022 W. Lehigh Ave., Philadelphia, Pa.
Kueter, J. B., (Student), Catholic Univ., Washington, D. C.
Lambert, A. L., (Student), Univ. of Pittsburgh, Pittsburgh, Pa.
Longest, W. G., 2422 W. Lafayette Ave., Baltimore, Md.
Maguire, D. B., 229 East Brown St., E. Stroudsburg, Pa.
Maio, C. R., Pennsylvania Power & Light Co., Lancaster, Pa.
Mathews, D. A., 1017 Red Oak St., Charleston, W. Va.
McCraven, M. R., 3144 Stanton Rd. S.E., Washington, D. C.
McGinnis, C. F., Elliott Co., Ridgway, Pa.
McNally, W. P., USAF Air Materiel Command, Dayton, Ohio
Mele, A. J., 2801 Ellsworth Ave., Erie, Pa.
Meyers, C. L., Pittsburgh Screw & Bolt Corp., Pittsburgh, Pa.
Miller, R., 172 Elizabeth Ave., Trenton, N. J.
Moore, J. G., Pennsylvania Transformer Co., Canonsburg, Pa.
Oerthel, R. H., 1075 Oxford Rd., Cleveland Heights, Ohio
Orr, J. R., R. C. A., Camden, N. J.
Ostroff, A., Technitrol Eng. Co., Philadelphia, Pa.
Patterson, R. W., Republic Steel Corp., Cleveland, Ohio
Petro, A. J., 814 Ridge St., Freeland, Pa.
Phelan, C. S., 402 Dale Drive, Silver Spring, Md.
Phipps, C. H., 125 North St., Bellevue, Ohio
Pietroski, R. W., Naval Air Development Station, Johnsville, Pa.
Plichta, E. J., Clark Controller Co., Cleveland, Ohio
Riddles, A. J., (Student), Catholic Univ., Washington, D. C.
Samans, E. W., Atlantic Refining Co., Philadelphia, Pa.
Schaefer, H. S., Jr., Wheeling Steel Corp., Yorkville, Ohio
Schwartz, C. J., 571 Noah Ave., Akron, Ohio
Senausky, P. V., 35 Montgomery Ave., West Pittston, Pa.
Shackelford, E. D., E. I. duPont de Nemours, Deepwater, N. J.
Silverman, J. B., 4922 N. 5th St., Philadelphia, Pa.
Sloan, C. E., Jr., 5549 Forbes St., Pittsburgh, Pa.
Smith, R. H., Jr., Union Switch & Signal Co., Pittsburgh, Pa.
Snyder, A. J., Jr., 7413 Sprague St., Philadelphia, Pa.
Sonnenfeldt, R. W., RCA Victor Div., Camden, N. J.
Spatt, O., Chase Aircraft Co., West Trenton, N. J.
Sterling, A. G., Jr., John T. Handy Co., Crisfield, Md.
Sticklen, W. E., 115 Oakwood Rd., Charleston, W. Va.
Suffoletta, J. R., 1021 Federal St., Toronto, Ohio
Svec, J. A., 5408 Belle Vista Ave., Baltimore, Md.
Tompkins, H. E., Moore School of Elec. Engg., Univ. of Pennsylvania, Philadelphia, Pa.
Trenbath, H. W., Jr., Air-Maze Corp., Cleveland, Ohio
Tucker, W. M., 4903 Crowson Ave., Baltimore, Md.
Uguccini, O. W., 3999 E. 123rd St., Cleveland, Ohio
Ulmer, R. M., 3041 E. 126th St., Cleveland, Ohio
Van Dine, H. A., Jr., General Elec. Co., Philadelphia, Pa.
Vilushis, T. P., 551 Cleveland St., Hazleton, Pa.
Wells, J. F., 19 Llandillo Road, Havertown, Pa.
Wisniansky, N. F., Pennsylvania Transformer Co., Canonsburg, Pa.
Wynn, F. X., 1019 Fawcett St., McKeesport, Pa.
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Chatigny, M. A., Naval Medical Research Unit No. 1, Univ. of Calif., Berkeley, Calif.
Clark, R. E., I. B. M. Inc., San Francisco, Calif.
Clock, D. P., 2110 W. 92nd St., Los Angeles, Calif.
Corbella, W. J., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Craig, L. J., 2531 Regent St., Berkeley, Calif.
Creighton, A. M., Jr., 2702 E. McDowell, Phoenix, Ariz.
Fuller, H. T., Airsupply Co., Los Angeles, Calif.
Gates, E. A., 5415 Mt. View, Riverside, Calif.
Gore, M. R., 136 N. Irving Blvd., Los Angeles, Calif.
Gotuaco, M. R., International House, Berkeley, Calif.
Hakala, P. E., 3915 Quarry Rd., La Mesa, Calif.
Hansen, G. M., 1624 N. Alexandria Ave., Hollywood, Calif.
Harris, E. R., 40 West Louise St., Long Beach, Calif.
Hart, J. G., Jr., California Elec. Power Co., Riverside, Calif.
Henschke, R. A., 3921 Woodruff Ave., Oakland, Calif.
Johnson, C. H., California Elec. Co., Riverside, Calif.
Kappel, T. J., 1822 W. 65th St., Los Angeles, Calif.
Keezer, D. C., 1011 Ninth St., Richmond, Calif.
Kiser, K. W., 31 Pilgrim Ave., San Francisco, Calif.
Larson, J. C., Box 725, McGill, Nev.
Lauerman, E. J., Salt River Valley Water Users' Assn., Phoenix, Ariz.
Leong, P. C., Pacific Fire Rating Bureau, San Francisco, Calif.
Mandler, C. H., 1200—17th Ave., San Francisco, Calif.
McLain, A. R., 1644 Bridge St., Oroville, Calif.
McPhate, J. A., 1402 No. San Gabriel Blvd., San Gabriel, Calif.
McQueen, A. H., Pacific Elec. Mfg. Corp., San Jose, Calif.
Messer, S., 3931 Fall Ave., Richmond, Calif.
Mitra, D. N., Old Dorm, Calif. Inst. of Tech., Pasadena, Calif.
Mulkey, R. H., Bureau of Reclamation, Phoenix, Ariz.
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Redlin, C. A., 147 No. Bradbury Dr., San Gabriel, Calif.
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Shepperd, R. R., 1323 Martin Ave., San Jose, Calif.
Stein, C. K., 5982½ Guthrie Ave., Los Angeles, Calif.
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Takemura, H. S., 804 Lincoln Ave., Pasadena, Calif.
Thal-Larsen, H., Bethlehem Steel Co., San Francisco, Calif.
Uhl, H. R., Pacific Elec. Mfg. Corp., San Francisco, Calif.
Walker, E. M., 1908 South Curson Ave., Los Angeles, Calif.
Yates, C. T., Jr., Central Arizona Light & Power Co., Phoenix, Ariz.

9. NORTH WEST

Anderson, M. W., Seattle City Light, Seattle, Wash.
Atkin, H. E., 1854 Redondo Ave., Salt Lake City, Utah
Bartu, A. S., Delta Chi Fraternity, Corvallis, Oreg.
Berdan, F. E., 1402 West 61st St., Seattle, Wash.
Berg, J. C., B. A. Travis, Seattle, Wash.
Bloodworth, J. L., 120—3rd St., Idaho Falls, Idaho
Bruck, R. H., 2822 N. E. 50th Ave., Portland, Oreg.
Bullock, D. L., 11415 NE 87 St., Kirkland, Wash.
Christensen, H. E., 430 12th Ave., Salt Lake City, Utah
Cockeram, D. J., R.F.D. #1, Oakland, Oreg.
Cole, N. E., Jr., Bonneville Power Admin., Portland, Oreg.
Cox, D. R., 1829 N.W. Lovejoy, Portland, Oreg.
Dressler, A. F., 8943-A S.W. 26th Ave., Portland, Oreg.
Ean, W. L., Fairbanks, Morse, & Co., Portland, Oreg.
Erwin, E. V., 4334 11th NE, Seattle, Wash.
Farr, R. F., 540 8th St., Ogden, Utah
Foster, W. G., Box 395 Route 1, Corvallis, Oreg.
George, L. E., 215 South 14th St., Salem, Oreg.
Hawes, D. J., Westinghouse Elec. Corp., Portland, Oreg.
Hooper, M. A., Pullman Appliance, Pullman, Wash.
Horton, L. S., Mountain States Power Co., Albany, Oreg.
Hoskinson, D. L., 1816 NE 12th Ave., Portland, Oreg.
Johnson, L. W., Boeing Airplane Co., Seattle, Wash.
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Kessler, V. C., Boeing Airplane Co., Seattle, Wash.
Lemman, R. L., Allis-Chalmers Mfg. Co., Seattle, Wash.
Lynch, J. N., Bonneville Power Admin., Portland, Oreg.
Martin, D. E., 403 N. 12., Corvallis, Oreg.
Matthews, M. M., 659 Jefferson, Corvallis, Oreg.
McKeown, W. G., Montana Power Co., Great Falls, Mont.
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Nado, L. J., Corps of Army Engrs., Walla Walla, Wash.
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Pyfer, D. H., Montana Power Co., Bozeman, Mont.
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Rogers, T., Fillmore, Utah
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Schmidt, R. W., 420 E. 12th St., The Dalles, Oreg.
Sethre, V. C., Bonneville Power Admin., Portland, Oreg.
Smith, R. R., Factory Insurance Assn., Seattle, Wash.
Tobin, T. H., U. S. Bureau of Reclamation, Coulee Dam, Wash.
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10. CANADA

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Dawson, G. P., Canadian Research & Development Est., Ottawa, Ont., Canada
Desjardins, R., Hydro-Quebec, Montreal, Que., Canada
Dickinson, J. G., Northern Elec. Co. Ltd., Montreal, Que., Canada
Earle, A. P., Jr., Shawinigan Water & Power Co., Montreal, Que., Canada
Fromm, W. F., 116 Sheridan Ave., Toronto, Ont., Canada
Gaudette, G. M., Sylvania Electric (Canada) Ltd., Drummondville, Que., Canada
Goldberg, D., Canadian Comstock Co. Ltd., F. C. D., St. Catherines, Ont., Canada
Handel, R. D., Hydro Elec. Power Comm., Toronto, Ont., Canada
Harris, A. J., Hydro Elec. Power Comm., Toronto, Ont., Canada
Howchin, E. R., General Elec. Co., Peterborough, Ont., Canada
Hucaluk, F. K., 1361 Langlois Ave., Windsor, Ont., Canada
Jowett, J. R., Commonwealth Elec. Corp. Ltd., Welland, Ont., Canada
Kuzniar, E., International Nickel Co. of Canada, Ltd., Copper Cliff, Ont., Canada
Louttit, C. C., Aluminum Co. of Canada, Ltd., Montreal, Que., Canada
McCarter, R. B., Canadian General Elec. Co., Davenport Works, Toronto, Ont., Canada
Mendel, A. H., Mendel & Brasloff, Montreal, Que., Canada
Merritt, R. D. V., Langley Mfg. Co., Ltd., Vancouver, B. C., Canada
Michael, E. S., c/o Canadian Comstock Co. F.C.D., St. Catherines, Ont., Canada
Milburn, J. V., 2371 Hamiota St., Victoria, B. C., Canada
Miller, V. R., Calgary Power Ltd., Calgary, Alberta, Canada
Milne, E. J., Canadian General Elec. Co., Toronto, Ont., Canada
Milovick, M., Admiralty House, HMCS Stadacona, Halifax, N. S., Canada
Modwel, B. P., Hydro Elec. Power Comm. of Ont., Toronto, Ont., Canada
Moulds, J. H., Canadian Patent Office, Ottawa, Ont., Canada
Paine, F. E., Ford Motor Co., Windsor, Ont., Canada
Palser, G. D., Canadian General Elec. Co., Toronto, Ont., Canada
Penman, M. D., British Columbia Tel. Co., Vancouver, B. C., Canada
Squires, F. M., Ferranti Elec., Mount Dennis, Ont., Canada
Stowe, G. F., Hydro Elec. Power Comm., Ottawa, Ont., Canada
Stuckey, L. R., Groundbirch, B. C., Canada
Taylor, J. D., British Columbia Power Comm., Victoria, B. C., Canada
Trussler, R. S., 9977 Jasper Ave., Edmonton, Alberta, Canada
Turland, D. J., Canadian General Elec. Co., Peterborough, Ont., Canada
Weskett, D. A., Hydro Elec. Power Comm. of Ont., Ont., Canada
Wilde, C. A. T., Amalgamated Elec. Corp., Toronto, Ont., Canada
Yates, R. A., General Elec. Co., Peterborough, Ont. Canada

Elsewhere

Char, J. S., Ibcon Ltd., Bombay, India
Hongskul, M., Directorate of Air Engg., Bangkok, Thailand
Kamal, A. K., Indian Inst. of Science, Bangalore, India
Kar, M. M., College of Engg. & Tech., Calcutta, India
Kayal, P. K., c/o Brook Motors Ltd., Huddersfield, England
Krishnaswami, N., Bombay Port Trust, Fort, Bombay, India
Mew, H. Y., Hawaiian Elec. Co., Honolulu, Hawaii
Nagi, P. S., P. W. D. Elec. Branch, Karnal, E. Punjab, India
Persson, T. V., South Swedish Power Co., Malmo, Sweden
Ramamurthi, G. K., The Crompton Engg. Co. (Madras) Ltd., Madras, South India
Roy-Bardhon, D. N., College of Engg. & Tech., Calcutta India
VanEck, G. W., Royal Dutch Shell Co., Curacao, Netherland, West Indies

Total to grade of Associate

United States, Canada and Mexico, 709
Elsewhere, 12

OF CURRENT INTEREST

1,857 Attend Annual ASTM Meeting; Morrow New Head; 4 Awards Made

At the 22 formal technical sessions and the several informal sessions and round-table discussions held during the 1949 annual meeting of the American Society for Testing Materials in Atlantic City, N. J., early last summer, upward of 185 papers and reports were presented. This was the 52d annual meeting of the society. The total registration, 1,857, was the second highest in the society's history, being exceeded only by the 1944 New York meeting.

One medal and three awards were presented at the meeting. The Charles B. Dudley Medal, awarded to the author or authors of an outstanding paper on research and engineering materials, was presented to six men: W. W. Buechner, R. J. Van de Graaff, H. Feshbach, A. Sperduto, on the staff of Massachusetts Institute of Technology (MIT), Cambridge, Mass.; and E. A. Burrill and L. R. McIntosh, formerly on the staff of MIT, now with High Voltage Engineering Corporation, Cambridge, Mass., for their paper on "An Investigation of Radiography in the Range From 0.5 to 2.5 Million Volts."

The Richard L. Templin Award, presented to the author of a noteworthy paper on new and useful testing procedures and apparatus, was given to W. T. Lankford, Research Associate, Research and Technology Department, Carnegie-Illinois Steel Corporation, Pittsburgh, Pa., for his paper on "Hydraulic Bulge Testing of Sheet Metals."

The Sanford E. Thompson Award, given in recognition of a paper of outstanding merit on concrete and concrete aggregates, was given to R. C. Mielenz and L. P. Witte, Head of Petrographic Laboratory and Durability Unit Materials Laboratories, respectively, Bureau of Reclamation, United States Department of the Interior, Denver, Colo., for their paper on "Tests Used by the Bureau of Reclamation for Identifying Reactive Concrete Aggregates."

The first Sam Tour Award, to encourage improvement of corrosion testing methods, was given to V. M. Darsey and W. R. Cavanagh, President and Research Chemist, respectively, Parker Rust Proof Company, Detroit, Mich., for their paper on "Apparatus and Factors in Salt Fog Testing."

James G. Morrow, Metallurgical Engineer, The Steel Company of Canada, Limited, Hamilton, Ontario, was elected President for 1949–1950, succeeding R. L. Templin, Assistant Director of Research and Chief Engineering of Tests, Aluminum Company of America, New Kensington, Pa., who continues on the Board of Directors as Past-President for three years. Frank E. Richart, Research Professor of Engineering Materials, University of Illinois, Urbana, Ill., is the new Vice-President to serve with the Senior Vice-President, L. J. Markwardt, Assistant Director, United States Forest Products Laboratory, Madison, Wis.

The new members of the Board of Directors are as follows: R. D. Bonney, Assistant Manager of Manufacturing, Congoleum-Nairn, Kearny, N. J.; C. H. Fellows, Head, Chemical Division, Research Department, The Detroit (Mich.) Edison Company; H. F. Gonnerman, Assistant to Vice-President for Research and Development, Portland Cement Association, Chicago, Ill.; N. L. Mochel, Manager, Metallurgical Engineering, Westinghouse Electric Corporation, Philadelphia, Pa.; and M. O. Withey, Dean of Engineering, University of Wisconsin, Madison, Wis.

Building Dedicated to Memory of Carpenter

The Mechanic Arts Building at the State College of Washington, Pullman, will be renamed the H. V. Carpenter Building next October 22 in honor of the former Dean of the College of Engineering, who served in that post from 1917 until his death in 1941. See biography of Mr. Carpenter (A '03, F '18) ***EE Jan '42, p 49***

MIT Offers Postgraduate Course Leading to "Engineer" Degree

A new terminal degree for practicing engineers, to be called the "engineer" degree, has been approved at the Massachusetts Institute of Technology (MIT), Cambridge. The degree of "engineer" will be recommended for students who complete an individually planned, 2-year program of study and research at the institute beyond their undergraduate degrees. Emphasis will be placed upon engineering practice rather than on the research which is characteristic of a program of study leading to a doctor of philosophy degree.

Most master's degree candidates at MIT require slightly more than one year of study to complete their work; candidates for the degree of "engineer," will require at least two years. This added time will result in more thorough training in a wider variety of relevant subjects, and also will enable students to delve more extensively into such fields as industrial economics, business administration, labor relations, and international affairs, thus improving their understanding of the social implications of the work in which they will be engaged.

When the field of specialization is to be indicated, the "engineer" degree will be referred to as follows: civil engineer, mechanical engineer, metallurgical engineer, electrical engineer, chemical engineer, sanitary engineer, marine mechanical engineer, naval architect, naval engineer, aeronautical engineer, building engineer, and meteorologist.

ECPD Reports on Its Study of Engineering-School Curricula

At a recent meeting of the Executive Committee of the Engineers' Council for Professional Development (ECPD), H. T. Heald, president of Illinois Institute of Technology and chairman of the Committee on Engineering Schools of the ECPD, announced that 106 engineering colleges have been visited by inspection committees during the past two years. A total of 481 curricula have been inspected, including 112 new curricular inspections. It is anticipated that by the end of the inspection year, a large share of the previously accredited curricula will have been reviewed and virtually all new curricula for which inspection has been requested will have been examined. The Committee on Engineering Schools is also studying the accreditation of graduate work in engineering.

The Committee on Professional Training, headed by A. C. Monteith, vice-president of Westinghouse Electric Corporation, is embarking upon a 7-point program, focusing attention upon improving the professional training in the postgraduation years. This program includes: a comprehensive survey of postgraduate programs in engineering colleges, industry, the government, and engineering societies; a study of methods of developing community-level programs aimed at improving the professional status and training of the engineer; an analysis of the professional registration of engineers; the encouragement of personal appraisal of the engineer in relation to his job, his community, and the engineering profession; a study of orientation and training programs in industry, with a view toward disseminating information along this line which will aid both large and small companies in developing suitable programs; the revision of selected bibliographies of engineering subjects; and the preparation of a selected reading list for young engineers. The latter two projects are nearing completion.

National Telemetering Forum Completes First Active Year

With the topic, "Requirements and Evaluation of Pickups," the seventh meeting of the National Telemetering Forum was held at the Bendix Aviation Corporation plant, South Bend, Ind., in May 1949. This meeting marked the end of the first year of activity for the forum which first met, for organizational purposes, at Johns Hopkins University, Silver Spring, Md., on May 6, 1948. The meetings are similar, as to manner of presenting papers and discussion, to AIEE Special Technical Conferences.

The National Telemetering Forum was brought about through the efforts of W. J. Mayo-Wells (M '44) an engineer with the telemetering group at the Applied Physics Laboratory of Johns Hopkins University, who realized the great need for a suitable medium to reduce duplication of effort in the interests of national economy and security. Preliminary plans were laid when a small representative group of telemetering men met during the Institute of Radio Engineers Convention in March 1948, and the first formal meeting was held on May 6. From the outset, those invited were purposely chosen to represent designers, manufacturers, users, and planners interested and actively engaged with telemetry. This diversity of representation served to stimulate the development of new ideas and to advance the art from every angle, and it is intended that the forum continue to serve as a source of such information, kept completely up to date, and always available.

By the end of 1948 the membership had grown to nearly a hundred organizations, and thus the following resolutions were adopted at the fifth meeting which took place November 8–9, 1948, at Waltham, Mass.

1. The name agreed upon for the organization is the National Telemetering Forum.
2. The group will not seek affiliation with any existing society or government agency, at least for the time being.
3. The membership shall be unrestricted. Interested organizations are invited to request that their names shall be added to the roll, as attendance shall be by invitation only.
4. Each meeting will last a minimum of two days.
5. Officers to carry out the minimum of essential business were elected as follows: *Chairman*, W. J. Mayo-Wells; *Vice-Chairman*, G. Adams (A '41), Boeing Aircraft Company, Seattle, Wash.; *Secretary*, H. B. Schultheis, Pacific Division, Bendix Aviation Corporation, North Hollywood, Calif.

Representatives of the AIEE met with the Chairman of the forum in New York, N. Y., in April 1949 to formulate plans for mutual education concerning each group's work in the field of telemetering, and it is expected that a joint AIEE/National Telemetering Forum Conference will be held sometime in the near future on subjects in this field of interest to both groups.

Lance Joins NBS Staff. H. W. Lance has been appointed to the staff of the National Bureau of Standards, where he will be concerned with electronic systems for guided missiles in the missile intelligence laboratory of the Bureau's electronics division. Lance has conducted research on electronic instrumentation for measurements in nuclear physics, antennas and transmission lines for use with radar systems, threshold signals for radar receivers, and cancellation devices for radar moving target indication. He was on the staff of the Naval Research Laboratory from 1942 until his appointment to the National Bureau of Standards. From 1938 to 1941 he was a graduate assistant in physics at Cornell University and in 1942 was a member of the faculty of Berea College.

Titus Joins Stanford Research Institute. Carl L. Titus has been appointed assistant director of Stanford Research Institute, Stanford, Calif. Mr. Titus has taken charge of Institute development and industrial service. His responsibilities now include the broadening of contacts with industry and extension of the institute's public service program. Previously, Mr. Titus was on the staff of the Armour Research Foundation, Chicago, Ill., where he was director of the magnetic recorder division, in charge of the foreign and domestic licensing program for the 35 patents the foundation holds on magnetic recording devices. During the war, he was with the Office of Scientific Research and Development, United States Navy. At New London, Conn., he supervised the installation and maintenance of sonar equipment for submarine detection aboard destroyers and escorts. For ten years before his war service, Mr. Titus was assistant manager of the radio division of the Montgomery Ward Company.

Felbeck Receives Plastics Award. The John Wesley Hyatt Award for distinguished achievement in plastics and a $1,000 cash prize were presented to Dr. George T. Felbeck, vice-president, Carbide and Carbon Chemicals Corporation, New York, N. Y., at the annual meeting of the Society of the Plastics Industry. Dr. Felbeck received the award for the engineering developments leading to the large-scale manufacture of polyethylene resins and plastics. Through his work, a plant was created during the war which supplied the United States Navy with the plastic vitally needed for the radar program. The process evolved by Dr. Felbeck for the production of polyethylene consists fundamentally of the pumping of ethylene to a pressure of approximately 30,000 pounds a square inch, and maintaining it at that pressure under controlled temperatures for the time necessary for polymerization.

Dr. Felbeck first became associated with the Union Carbide and Carbon Corporation in 1923. Since 1943, he has supervised work in three installations which his company operates for the Atomic Energy Commission at Oak Ridge, Tenn.

Future Meetings of Other Societies

American Chemical Society. 116th National Meeting. September 19–23, 1949, Atlantic City, N. J.

American Gas Association. Annual Convention. October 17–20, 1949, Palmer House, Morrison Hotel, and Sherman Hotel, Chicago, Ill.

American Institute of Chemical Engineers. September 6–9, 1949, Mount Royal Hotel, Montreal, Quebec, Canada. November 7–10, 1949, Hotel William Penn, Pittsburgh, Pa.

American Society of Mechanical Engineers. Fall meeting, September 28–30, 1949, Erie, Pa. Annual meeting, November 27–December 2, 1949, Hotel Statler, New York, N. Y.

American Society for Testing Materials. West Coast Meeting. October 10–14, 1949, Fairmount Hotel, San Francisco, Calif.

American Standards Association. Annual Meeting, October 11–14, 1949, Waldorf-Astoria Hotel, New York, N. Y.

Engineers' Council for Professional Development. October 28–29, 1949, Edgewater Beach Hotel, Chicago, Ill.

Exposition of Chemical Industries. November 28–December 3, 1949, Grand Central Palace, New York, N. Y.

Illuminating Engineering Society. National Technical Conference. September 19–23, 1949, French Lick, Ind.

Instrument Society of America. Annual meeting and exhibit. September 12–16, 1949, Municipal Auditorium, St. Louis, Mo.

International Scientific Radio Union-Institute of Radio Engineers. October 31–November 2, 1949, National Academy of Sciences and New State Department Building, Washington, D. C.

Iowa Utilities Association Management Conference. October 10–11, 1949, Hotel Fort Des Moines, Des Moines, Iowa.

National Conference on Industrial Hydraulics. Fifth Annual Meeting. October 26–27, 1949, Sheraton Hotel, Chicago, Ill.

National Electrical Contractors Association. Annual Convention, November 7–10, 1949, Rice Hotel, Houston, Tex.

National Electrical Manufacturers Association. November 13–18, 1949, Chalfonte-Haddon Hall, Atlantic City, N. J.

National Electronics Conference. September 26–28 1949, Edgewater Beach Hotel, Chicago, Ill.

National Safety Congress and Exposition. October 24–28, 1949, Stevens, Congress, and Morrison Hotels, Chicago, Ill.

National Television and Electrical Living Show. Second Annual Meeting. September 30–October 9, 1949, Chicago Coliseum, Chicago, Ill.

Pacific Industrial Conferences-Pacific Chemical Exposition. November 1–5, 1949, San Francisco Civic Auditorium, San Francisco, Calif.

Petroleum Electric Power Association. Annual Conference. November 17–18, 1949, Hotel Beaumont, Beaumont, Tex.

Radio Manufacturers Association-Institute of Radio Engineers. 1949 Radio Fall Meeting. November 1–2, Hotel Syracuse, Syracuse, N. Y.

Scottish Industries Exhibition. September 1–17, 1949 Kelvin Hall, Glasgow, Scotland.

Society of Automotive Engineers. Aeronautic Meeting and Aircraft Display. October 5–8, 1949, Biltmore Hotel, Los Angeles, Calif.

Society of Motion Picture Engineers. 66th Semiannual Convention. October 10–14, 1949, Hollywood-Roosevelt Hotel, Hollywood, Calif.

Fellowships in Power Systems Engineering. Westinghouse fellowships in power systems engineering at Illinois Institute of Technology, Chicago, have been awarded to Richard P. Burandt, Wood Dale, Ill., and Samuel C. Caldwell, Kansas City, Mo. Made possible through a grant to the institute by the Westinghouse Education Foundation, the fellowship originally provided for free tuition and $1,500 to one applicant for three semesters of study leading to a master's degree in electrical engineering. Because the two most outstanding candidates, Burandt and Caldwell, are both veterans receiving some financial aid under the G. I. Bill, the total award was divided between them. Burandt is an instructor in electrical engineering at Rose Polytechnic Institute, Terre Haute, Ind. Caldwell, now a senior at the Illinois Institute of Technology, will receive his bachelor's degree in June. Both begin the first of three semesters work in September.

RMA Elects Cosgrove President. Raymond C. Cosgrove, executive vice-president of the Avco Manufacturing Corporation, Cincinnai, Ohio, who served the Radio Manufacturers Association (RMA) as president for three consecutive years, 1944 to 1947, again will direct the activities of the association as it begins its 26th year. He was recalled to service by the RMA board of directors for a fourth term at the "Silver Anniversary" convention. President Cosgrove succeeds Max F. Balcom, vice-president of Sylvania Electric Products Inc., Emporium, Pa., who declined to be a candidate for re-election following two years as RMA president. Also, five new RMA directors were elected and Mr. Cosgrove was returned to the board, succeeding John W. Craig, vice-president and general manager of the Crosley Division, Avco Manufacturing Corporation. Nine other directors were re-elected.

Foreign Study Booklet Issued. A handbook of opportunities for study in foreign countries has just been issued by the United Nations Educational, Scientific, and Cultural Organization, listing 10,500 opportunities for international study in 166 subject fields in 27 countries. The largest number of the awards will be in science, particularly engineering, chemistry, public health, and medicine. Entitled "Study Abroad," the handbook is available at $1 per copy from the Columbia University Press, New York 27, N. Y.

Joint IRE-RMA Committee Officers Named. Donald G. Fink (M '45) and John V. L. Hogan (A '11, M '20), Fellows of the Institute of Radio Engineers, have been appointed Chairman and Vice-Chairman respectively of the Joint Technical Advisory Committee by the Boards of Directors of the Institute of Radio Engineers and the Radio Manufacturers' Association. Laurence G. Cumming (M '47), Senior Member of the Institute of Radio Engineers, was reappointed secretary of the Joint Technical Advisory Committee. All three will serve for the term July 1, 1949, through June 30, 1950. Formed jointly by the Institute of Radio Engineers and the Radio Manufacturers' Association in May 1948, the Joint Technical Advisory Committee reviews and evaluates technical and engineering information relating to electronics in order to advise Government bodies and other professional and industrial groups. Currently the committee is assisting the Federal Communications Commission in its deliberations concerning the future use of frequencies from 475 to 890 megacycles for television. It has issued two reports on this subject in connection with recent Commission hearings.

New HKN Chapter in Connecticut. The Beta Omega Chapter of Eta Kappa Nu Association (HKN) was formally installed by Robin Beach (A '15, F '35), formerly Vice-President, and now National President, of HKN, at the University of Connecticut, Storrs, late last spring. Twenty-eight electrical engineering students and 14 others were initiated in a ceremony arranged by A. B. Zerby (A '38), Executive Secretary of HKN. A dinner address was given by Victor Siegfried (A '32, M '38), Vice-President of the AIEE, District 1, who also was initiated as a member of the HKN on this occasion.

Engineering Colleges Group Elects Officers. At a recent meeting of the Association of Engineering Colleges of New York State, the following officers were elected for the 1949–50 term: President—Professor Harold W. Bibber, Chairman, Division of Engineering, Union College, Schenectady, N. Y.; Vice-President—William Allan, Dean, School of Engineering, College of the City of New York (N. Y.); Secretary-Treasurer—Brother Amandus Leo, Dean, School of Engineering, Manhattan College, New York, N. Y. Fifteen New York state colleges belong to the association.

Ordnance Building Dedicated to Diamond. Dedication ceremonies for the Harry Diamond Ordnance Laboratory were held late last spring at the National Bureau of Standards in the presence of representatives of Government and industry. The ceremonies were climaxed by the unveiling of a memorial plaque on the Bureau's ordnance laboratory which names it the "Harry Diamond Ordnance Laboratory." Speakers at the dedication were: the Honorable Charles Sawyer, Secretary of Commerce; Major General E. S. Hughes, Chief of Ordnance, Department of the Army; Rear Admiral A. G. Noble, Chief of the Bureau of Ordnance, Department of the Navy; and Major General R. C. Coupland, Director of Armament, United States Air Force. Mr. Diamond, who died in 1948, pioneered in the development of the Instrument Landing System, a system for the blind landing of aircraft. He also helped to develop radiosonde, a device for collecting weather information from the upper atmosphere, and was one of the inventors of the proximity fuse. For a biography of Mr. Diamond (F '47), see *EE, Aug 48, p 790.*

Electronic Index Has New Publishers. John F. Rider has acquired all properties and copyrights of the Electronic Research Publishing Company, New York, N. Y., publishers of the Electronic Engineering Master Index, as well as the Electronic Engineering Patent Index. The new organization, known as the Electronic Research Publishing Company, Inc., of which Mr. Rider is president, will expand both compilation and publishing activities of these two indexes, so as to include the full gamut of foreign as well as domestic sources of electronic data. It will embrace within its activities, a complete bibliography research service for electronic engineering laboratories, colleges, libraries, and other institutions who desire information on published technical articles. In addition, the organization will publish electronic engineering texts. Publication of bibliography references will be established on a quarterly, semiannual, and annual basis. Headquarters will be maintained at 480 Canal Street, New York 13, N. Y.

IES National Technical Conference. A review of significant lighting achievements of the past year will make up the program of the National Technical Conference of the Illuminating Engineering Society (IES) scheduled for September 19–23, 1949, at French Lick, Ind. The technical sessions of the conference will feature symposia on light sources, color, street lighting, and residence lighting. Also at the conference, C. H. Goddard of Sylvania Electric Products, Inc., will be installed as IES President, and Dr. Ward Harrison, retired Director, Engineering Division, General Electric Company, will be presented the IES Gold Medal and Award Certificate.

H. E. Fritz Honored by Ohio State. Dr. Howard E. Fritz, Vice-President of Research, The B. F. Goodrich Company, has been named 1949 winner of the Lamme Medal of Ohio State University, Columbus. The award is made yearly to a graduate of an Ohio State technical department for "meritorious service in engineering of the technical arts." Dr. Fritz pioneered in the adoption of rubber-lined steel products as chemical engineering tools for the handling of corrosive liquids. He holds four degrees from Ohio State—bachelor of chemical engineering, master of science, professional degree of chemical engineer, and doctor of philosophy.

F. D. Snell Gets British Chemistry Medal. Dr. Foster Dee Snell, chemical consultant of New York, N. Y., recently was presented the gold medal of the Society of Chemical Industry at its meeting in Manchester, England. This is the second time in its 53-year history that this medal has been awarded to an American. It is given biennially by the society's council to a person "who has attained eminence in applied chemistry." Dr. Snell's specialty is surface active phenomena, which embraces the action of soaps, detergents, wetting agents, and similar products. He has been a consulting chemist for nearly 30 years.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Measuring Heavy Direct Currents

To the Editor:

The article, "Measuring Heavy Direct Currents," (*EE, Mar '49, p 242*) says that a static d-c transformer has long been a "sought-after impossibility" until Westinghouse engineers invented the "Transductor."

In fact, however, only the name is new, the device has been published and manufactured in Europe during the past 30 years. The original inventor is E. Besag; he published the d-c transformer in the *Elektrotechnische Zeitschrift*, 1919, page 436. His German patent had been filed six years earlier, August 21, 1913, No. 272,748.

Improvements were later made by

Voigt and Haeffner (German Patent 315,945)
Keinath (German Patent 386,332) filed September 1, 1922
Rottsieper (Allgemeine Elektrizitaetsgesellschaft)
V 3216—1, 1933 *Archiv fuer Technisches Messen*
Someda (L'Elettrotecnica 1935, page 206)
Kraemer (Allg. El. Ges., Elektrot. Z. 1937, page 1309)
Ritz (Siemens and Halske)

There are many publications, summary reports you may find in the *Archiv fuer Technisches Messen* ("*ATM*")

V 3213—1, December 1932
V 3216—1, August 1933
V 3213—2, September 1938
V 3213—3, November 1939

A British d-c transformer with the ratio 40,000/10 amperes (d-c to a-c) has been described in *Electrical World* of August 23, 1941, from *Electrical Review*.

I wonder whether all these publications on the subject and the fact that such transformers were in production abroad were unknown to Westinghouse engineers. The performance of these earlier d-c transformers was fully satisfactory. A 20,000/5 ampere transformer built by Kraemer delivered 30 volt-amperes with an accuracy of +0.5 per cent within 10 and 120 per cent of rated current.

It does not look that the d-c transformer was in one class with the perpetuum mobile.

GEORGE KEINATH (M '37)

(Larchmont, N. Y.)

Exponential Rise

To the Editor:

I have been rather a long time getting round to the May issue of *Electrical Engineering*, and so have just seen the letter by Charles Ammerman on "Exponential Rise" (*EE, May '49, p 468*).

I too have not seen the proof of the use of semilog paper for straightening an exponential curve, but on the European side of the Atlantic at least, its use is widespread. As evidence of this I would remark that British Standard Specification 173, clause 22, page 11, relating to traction motors, specifies this method for the extrapolation of armature cooling curves at zero time.

In a more empirical manner, semilog or log-log paper can be used for making acutely curved graphs more nearly straight. I have used this often to ease the job of interpolating values among experimental points, even when there is no particular law to the curve to justify the use of this special paper. As Worthing and Geffner ("Treatment of Experimental Data") point out, the more nearly a curve approaches a straight line, the easier it is to deal with the figures accurately.

FRANK W. ROBERTS (M '45)

("Ashdown," Western Road, Billericay, Essex, England)

4-Terminal Network

To the Editor

I must concede to Mr. Kroneberg that in his letter to the editor (*EE, Feb '49, p 186*) he does solve my "4-Terminal Network" problem (*EE, Nov '48, p 1073*) very neatly using all six transformers actively.

May I return the compliment to Mr. Kroneberg.

J. SLEPIAN (F '27)

(Associate Director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Increasing Quartz Crystal "Q"

To the Editor:

The importance of quartz crystal unit for frequency control derives from the very high Q (ratio of reactance to resistance) and the low frequency-temperature coefficient of quartz, and the very steep slope of the reactance curve of the crystal blank. The Q of quartz is higher than that of any other frequency controlling device used to date.

The Q and frequency of a given quartz crystal blank change, however, with time; these changes are results of the so-called aging process. During World War II, crystal units were used in very large quantities in military communications equipment. Considerable difficulty was experienced during the first years of the war because the useful life of a crystal unit was greatly reduced by reason of its "aging out of frequency" or "going dead." A usable reduction in aging was later accomplished during 1944 by etching the surfaces of the crystal blanks. This only mitigated the effect, however, and its more complete elimination was highly desirable.

A method has recently been developed at the Signal Corps Engineering Laboratories, Fort Monmouth, N. J., whereby the Q-value of the quartz blank has been materially increased, and the aging has been very greatly reduced. The method consists of annealing the quartz blank by heating it almost to the inversion temperature of quartz, or 500 degrees centigrade, and cooling it down extremely slowly.

This simple treatment yields values of Q which are at least double those of untreated quartz blanks, and variations in frequency and Q are minute. These improvements in Q and aging characteristics appear to be of a permanent character.

A paper describing the results in greater detail is in preparation.

A. C. PRICHARD, M. A. A. DRUESNE,
D. G. McCAAN

(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)

Illumination Terms

To the Editor:

So Professor Abramowitz objects (*EE, Jun '49, pp 559–60*) to Dr. Goldmark's use of the foot-lambert as a unit of illumination (*EE, Mar '49, pp 237–42*). I thought everyone knew that such lapses are in the best tradition in writings on photometry. The author is merely playing a game with his readers for the amusement of those who understand.

Professor Abramowitz should know this as well as anyone. In fact, he does it himself. He says "The unit of illumination is foot-candles and refers to light flux per square foot falling normal to the surface." He means, I think, light flux per square foot of surface, period. Again, he says, "Thus, while both foot-candles and foot-lamberts have the same dimensions, that is, 'lumens per square foot,' physically they are quite different." He means, I think, that foot-candles have the dimensions of lumens per square foot, while foot-lamberts have the dimensions of lumens per steradian per square foot.

I must concede Professor Abramowitz a distinct edge over Dr. Goldmark in one respect—he plays the game with more finesse.

MILLARD W. BALDWIN, JR.

(Bell Telephone Laboratories, Murray Hill Laboratory, Murray Hill, N. J.)

To the Editor:

I have read Professor Abramowitz's letter carefully in which he states that I have misused the term foot-lambert. Perhaps it was a mistake on my part not to have spelled out the exact method of measuring the illumination surrounding the receiver. A white card was placed next to the receiver, and the light reflected from that card was measured with a Macbeth Illuminometer as 20 foot-lamberts. In view of more important issues which were involved in the article, I did not feel that it was necessary to give such a detailed explanation of this; and I sincerely hope that I have succeeded in putting across my fundamental ideas to most of your readers.

I greatly appreciate the comments addressed to you by Dr. Baldwin, who has come to my rescue in this matter.

PETER C. GOLDMARK (M '45)

(Director, Engineering Research and Development Department, Columbia Broadcasting System, Inc., New York, N. Y.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

TRANSFORMATIONS ON LATTICES AND STRUCTURES OF LOGIC. By Stephen A. Kiss. Published by Stephen A. Kiss, 11 East 92d Street, New York, N. Y. 322 pages, diagrams, tables, $10^{1}/_{4}$ by 7 inches, cloth. A study of the symmetries of certain abstract structures written as a guide for those interested in the development of 4-class logic and mathematics. Subject matter deals mainly with Boolean algebras, including such topics as structures; sets, groups, and rings; partially ordered systems and lattices; link-preserving transformations; Boolean algebras; direct unions of chains, number systems; and the calculus of classes, of propositions, and of propositional functions. A bibliography and index are included.

ROYAL SOCIETY NEWTON TERCENTENARY CELEBRATIONS, July 15–19, 1946. University Press, Cambridge, England; Macmillan Company, New York, N. Y., 1947. 92 pages, illustrations, $10^{1}/_{4}$ by $6^{1}/_{2}$ inches, cloth, $3. This book contains the record of the celebration of the 300th anniversary of the birth of Isaac Newton. The lectures and addresses deal either with Newton as a man or with separate aspects of his work. Much of the book is for skilled readers only, but several lectures are intelligible to the layman.

SPHERICAL HARMONICS. By T. M. MacRobert, Second edition revised. Dover Publications, New York. N. Y., 1947. 372 pages, diagrams, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches cloth, $4.50. An elementary treatise on harmonic functions for students with a knowledge of calculus but unfamiliar with the method of contour integration or the modern theory of functions of a real variable. On this same basis the book treats Fourier series, Bessel functions, the hypergeometric function, and associated Legendre functions. Considerable space has been devoted to applications in mathematical physics and engineering.

TABLES OF THE BESSEL FUNCTIONS OF THE FIRST KIND OF ORDERS 28 THROUGH 39. (Annals of the Computation Laboratory of Harvard University, volume 10.) By the staff of the Computation Laboratory. Harvard University Press, Cambridge, Mass., 1948. 694 pages, tables, $11^{3}/_{4}$ by $7^{3}/_{4}$ inches, cloth, $10. Eighth of the series begun in 1947 with tables of the orders zero and one, the present volume continues to present the tables computed on the automatic sequence controlled calculator. Bessel functions of orders 40 through 100 are to be published subsequently. The tabulation in the current volume is carried to 10 decimal places.

THEORETISCHE ELEKTROTECHNIK, BAND 2. Grundzüge der Theorie des Wechselstromkreises und des einphasigen Transformators. (Lehr- und Handbücher der Ingenieurwissenschaften 12.) By K. Kuhlmann. Verlag Birkhäuser, Basel, Switzerland, 1947. 175 pages, diagrams, charts, tables, $9^{3}/_{4}$ by $6^{1}/_{2}$ inches, linen, 26.50 Sw. frs.; unbound, 22.50 Sw. frs. This book treats analytically and graphically the principles of a-c circuits and single-phase a-c transformers. The representation in analytical form is based on the use of the theory of complex numbers and the geometrical location of points. Among the special topics dealt with are the influence of iron and saturation and leakage phenomena.

TRANSFORMERS, PRINCIPLES AND APPLICATIONS. By C. H. Dunlap, W. A. Siefert, and F. E. Austin. American Technical Society, Chicago 37, Ill., 1948. 277 pages, illustrations, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $2.75. Written for the practical man, this book is a thorough treatment of the subject and is organized for instant application to the job. It is divided into three parts: construction; theory, connections and operations; and the design of small transformers. The electrical and magnetic principle necessary for the understanding of the subjects discussed are included.

TRANSFORMERS, THEORY AND CONSTRUCTION. By W. C. Sealey. International Textbook Company, Scranton, Pa., 1948. Paged in sections, illustrations, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{4}$ inches, cloth, $3. Stressing modern practice, this volume considers transformer history, theory, calculations, construction, and application. It presents the fundamental principles so as to provide an introduction and a working knowledge of transformers. Material which is of academic interest only is omitted, but the author has covered a wide variety of special transformers for unusual applications.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

TRENDS IN ENGINEERING EDUCATION, THE COLUMBIA EXPERIENCE. By J. K. Finch. Columbia University Press, New York, N. Y., 1948. 140 pages, charts, tables, 8 by $5^{1}/_{2}$ inches, cloth, $2. Although presenting the philosophy of education of one particular school, the Columbia school of engineering, this small volume should be of interest to all engineering educators. Two of the most important problems discussed are the broadening of engineering curricula to include basic subjects of general education and the advancement of graduate instruction and research in engineering science. Teaching methods and the problem of faculty appointments have not been considered.

UNDERSTANDING TELEVISION. By O. E. Dunlap, Jr. Greenberg, Publisher, 201 East 57th St., New York, N. Y., 1948. 128 pages, illustrations, diagrams, maps, tables, 8 by $5^{1}/_{4}$ inches, cloth, $2.50. Written for the layman, this volume is a simple, direct explanation of what television is and how it works. Following an historical survey is discussion of the television camera, antennas and relay station, coaxial cable, and the receiver. The techniques involved in putting together a television program, both in the studio and in the field, are considered. There is a glossary.

MATHEMATICS AT WORK. By H. L. Horton. Industrial Press, New York 13, N. Y., 1949. No pagination, diagrams, tables, $9^{1}/_{4}$ by 6 inches, fabrikoid, $6. A working manual for machine designers, tool engineers, gauge designers, mechanical draftsmen, and technical or trade students. It reviews the fundamentals of arithmetic, algebra, geometry, and trigonometry. There is a comprehensive discussion of problems and their solution and an explanation of special aids in computation.

MECHANICAL VIBRATIONS. By W. T. Thomson. Prentice-Hall, New York, N. Y., 1948. 222 pages, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $5. Based on courses presented at the University of Wisconsin, this book presents the fundamentals of vibration theory and provides a general background for advanced study in the field. The student is assumed to have an elementary knowledge of calculus, dynamics, and strength of materials.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

NEMA Standards. Two standards recently published are "Standards for Mining Belt Conveyors," Publication Number 49-142, and "Standards for Rubber-Insulated Power and Control Cables," Publication Number 49-141. The first covers sectional-type electrically driven conveyors. The latter describes cable construction, test requirements, and the dimensions of components. 49-142 sells for 50 cents, and 49-141 for $3. Four other standards available are: "Black Varnished Condenser Paper," 48-137; "Yellow Varnished Condenser Paper," 48-138; "Yellow Varnished Nylon Fabric," 48-139; "Yellow Varnished Silk Fabric," 48-140. These are priced at 60 cents per copy. Address orders to National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

Manual on Photomicrography, PB 92781. The instruments of photomicrography, their theory and techniques, are discussed in this manual prepared by the Carl Zeiss Company of Germany and translated by the Air Force. Available at $17.50 in photostat and $5.50 in microfilm from the Librarian of Congress, Photoduplication Service, Publication Board Project, Washington 25, D. C.

Optical Glass at the National Bureau of Standards. A description of procedures used by the bureau in its expermental glass plant. Available at 15 cents per copy from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C.

High-Speed and Motion-Picture Photography. A 129-page booklet covering electrical flash photography, a new high-speed stroboscope, motion-picture equipment for very-high-speed photography, and industrial and scientific applications of high-speed photography. May be purchased for $1.50 from the Society of Motion Picture Engineers, 342 Madison Avenue, New York 17, N. Y.

Department of Commerce Releases. "Some Fundamental Aspects of Telemetering," Report PB93938, dealing with inherent problems. 73 pages. Photostatic copy, $10; microfilm copy, $3.50; "Rotating Electrical Machinery, Transformers and Electric Traction," Report PB93859, a summary on electric motors, generators, and transformers from a review of industrial practice in Germany. 258 pages. Photostatic copy, $32.50; microfilm copy, $9. Available from the Library of Congress, Photo-duplication Service, Publication Board Project, Washington 25, D. C.

Carbon Dioxide Protection of Fur-Storage Vaults, Subject 172B. A report including test procedure and equipment, salvage evaluation, observations, and summaries. Available from the Underwriters' Laboratories, Inc., 207 East Ohio Street, Chicago 11, Ill.

National Bureau of Standards Publications. Circular 469, "Optical Glass at the National Bureau of Standards," a description of the NBS plant for the production of optical glass. 15 cents a copy; Circular 470, "Precision Resistors and Their Measurement," on the practical limitations of resistance-measuring bridges. 20 cents a copy; "Simplified Practice Recommendation R233-48, Rotary Files and Burs," based on consumer requirements. 10 cents a copy. All available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.